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CONDITIONAL RISK PREMIA IN CURRENCY MARKETS AND OTHER ASSET CLASSES

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ABSTRACT

The downside risk CAPM (DR-CAPM) can price the cross section of currency returns. The market-beta differential between high and low interest rate currencies is higher conditional on bad market returns, when the market price of risk is also high, than it is conditional on good market returns. Correctly accounting for this variation is crucial for the empirical performance of the model. The DR-CAPM can jointly rationalize the cross section of equity, equity index options, commodity, sovereign bond and currency returns, thus offering a unified risk view of these asset classes. In contrast, popular models that have been developed for a specific asset class fail to jointly price other asset classes.

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An online appendix is available at:
http://www.nber.org/data-appendix/w18844

1. Introduction

Foreign exchange is a potentially risky investment and the debate on whether currency returns can be explained by their association with risk factors remains ongoing. We find that the cross section of currency returns can be explained by a risk model where investors are concerned about downside risk. High yield currencies earn higher excess returns than low yield currencies because their co-movement with aggregate market returns is stronger conditional on bad market returns than it is conditional on good market returns. We find that this feature of the data is characteristic not only of currencies but also of equities, commodities, sovereign bonds and other test assets thus providing a unified risk view of these markets.

The carry trade in foreign exchange consists of investing in high yield currencies while funding the trade in low yield currencies. This trading strategy has historically yielded positive returns because returns on high yield currencies are higher than returns on low yield currencies. A number of explanations for this cross-sectional dispersion have been advanced in the literature, varying from risk based to behavioral.

We suggest a risk-based explanation by showing that the downside risk capital asset pricing model (DR-CAPM) prices the cross section of currency returns. We follow Ang, Chen, and Xing [2], who study equity markets, by allowing both the market price of risk and the beta of currencies with the market to change conditional on the aggregate market return. Intuitively, the model captures the changes in correlation between the carry trade and the aggregate market returns: the carry trade is more correlated with the market during market downturns than it is during upturns.

Correctly capturing the variations in betas and prices of risk is crucial to the empirical performance of the DR-CAPM. It also clarifies why the unconditional CAPM does not explain the cross section of currency returns. While high yield currencies have higher betas than lower yield currencies, the difference in betas is too small to account for the observed spread in currency returns.

We extend our results by testing the performance of the DR-CAPM jointly on currencies, various equity portfolios, equity index options, commodities and sovereign bonds. The variations in betas and prices of risk in the DR-CAPM can jointly capture the cross-sectional returns of all of these asset classes. This contrasts with the inability of a number of asset-class-specific models to price asset classes other than the one for which they have been built.

The economic intuition behind our results is summarized in Figure 1. Across different asset classes such as currencies, commodities, and equities, assets that have higher exposure to downside risk, that is assets that have a higher downside beta (β^-), earn higher excess returns even when controlling for their CAPM beta (β).[4] The top panel of Figure 1 highlights this pattern in the data by plotting realized average excess returns versus the corresponding asset loading on downside risk ($\beta^- - \beta$). The positive relationship between expected returns and

[4] See Sections 2-3 for the precise definition and estimation procedure of β and β^-.

downside risk is the crucial pattern behind the more formal econometric analysis of this paper. In contrast, the bottom panel of Figure 1 shows why the CAPM cannot price the returns of these asset classes. Within each asset class there is little dispersion in betas but a larger dispersion in realized returns. Across asset classes the CAPM captures, at best, the average return of each asset class, but no strong systematic relationship appears.

We compare the DR-CAPM with models based on principal component analysis (PCA) both within and across asset classes. Within each asset class the DR-CAPM captures the cross-sectional dispersion in returns summarized by the most important principal components. Across asset classes the DR-CAPM continues to capture expected returns with only two fundamental factors, while a PCA-based model requires as many as eight factors to generate similar explanatory power.

This paper contributes to two strands of literature: the international finance literature on exchange rates and currency returns and the asset pricing literature on the joint cross section of returns of multiple asset classes.

Among a vast international finance literature, Lustig and Verdelhan [36] provide an explanation for the cross section of currency returns based on the Durable Consumption CAPM (DC-CAPM). Burnside [9] and Lustig and Verdelhan [37] discuss the association of currency returns with consumption growth. Burnside, Eichenbaum, Kleshchelski, and Rebelo [10], Burnside, Eichenbaum, and Rebelo [12, 11], Burnside, Han, Hirshleifer, and Wang [13] focus on explanations of the carry trade such as investor overconfidence and peso problems. Lustig, Roussanov, and Verdelhan [35] (LRV) provide a model that employs the principal component analysis of currency returns. They show that currencies that load more heavily on the first two principal components, approximated by the returns on a dollar and carry trade portfolio respectively, earn higher excess returns on average. Menkhoff, Sarno, Schmeling, and Schrimpf [40] link the carry trade factor to exchange rate volatility.

Our contribution to this literature is to provide an explanation of currency returns based on the *conditional contemporaneous* association of currency returns with a traditional risk factor, the market return. We not only reconcile our findings with the more statistical factors used in the literature, but also show that currencies are affected by the same aggregate risk that drives expected returns in other assets classes such as equities and commodities.

A nascent literature is exploring the joint cross section of returns in multiple asset classes. Cochrane [18] emphasized this research agenda, which aims to reconcile the discount factors in different asset classes. In his American Finance Association presidential address he ponders: "*What is the factor structure of time-varying expected returns? Expected returns vary over time. How correlated is such variation across assets and asset classes? How can we best express that correlation as factor structure? [...] This empirical project has just begun, [...] but these are the vital questions.*"

In recent and ongoing research Asness, Moskowitz, and Pedersen [3], Frazzini and Pedersen [27], Koijen, Moskowitz, Pedersen, and Vrugt [32] document that a number of cross-sectional phenomena such as value, carry, momentum, and the slope of the unconditional-CAPM-based capital market line that were previously only documented for specific asset classes are actually pervasive across multiple asset classes. We contribute to this literature by showing that the DR-CAPM can jointly reconcile the cross-sectional dispersion in returns across multiple asset classes. We also explore the factor structure by comparing the model to several PCA-based models. We find that PCA-based models tailored to a specific asset class are unable to price other asset classes, and that a PCA model based on the joint cross-section of multiple asset classes overestimates the number of risk factors. We view our results as a step in the research agenda emphasized by Cochrane [18].

We stress that the purpose of this paper is not to suggest that the DR-CAPM is the "true" model of all asset prices, nor is it to discourage the use of PCA to summarize patterns in asset returns. The purpose of this paper is to show that the cross sectional variation in returns across asset classes can be captured by the association of returns, both unconditionally and conditionally, with a traditional risk factor, the market return. For this purpose and for completeness, we also report in Section 6.5 a number of assets that the the DR-CAPM does not price well.

In a separate online appendix we provide a number of details, robustness checks, and extensions of our results that are omitted in the main body of the paper, including a comparison of the DR-CAPM with PCA and co-skewness models.

2. Carry Trade, Cross-Sectional and Market Returns

We follow Ang et al. [2] in allowing a differentiation in unconditional and downside risk. This captures the idea that assets that have a higher beta with market returns conditional on low realization of the market return are particularly risky. The economic intuition underlying downside risk is simple: agents not only require a premium for securities the more their returns covary with the market return, but also, and even more so, when securities covary more with market returns conditional on low market returns. Markowitz [39] was among the first to recognize the importance of downside risk, formalized in his "semi-variance", in addition to his more canonical expected-return-variance framework.[5] While Ang et al. [2] motivate the above insight using the disappointment aversion model of Gul [29] further extended by Routledge and Zin [44], a variety of models are potentially consistent with our findings.[6]

The main insight of this paper is that downside risk is a prevalent feature in many asset classes. We show that expected returns in currency, equity, commodity, sovereign bond and option markets can be explained by a simple beta that measures the downside risk of assets in these asset classes. To capture the relative importance of

[5]Markowitz [39][Ch. 9] notes that "variance is superior with respect to (computational) cost, (analytical) convenience, and familiarity. (However), analyses based on semi-variance tend to produce better portfolios than those based on variance".

[6]A variety of other asymmetrical CAPM models have been derived, for example: Leland [34] and Harvey and Siddique [30]. Adrian, Etula, and Muir [1] test a model of financial constraints and leverage in which the discount factor loads on negative outcomes for broker-dealer firms.

downside risk we propose that expected returns follow:

$$\begin{aligned} E[r_i] &= \beta_i \lambda + (\beta_i^- - \beta_i)\lambda^- \qquad i = 1, \ldots, N, \\ \beta_i &= \frac{cov(r_i, r_m)}{var(r_m)}, \\ \beta_i^- &= \frac{cov(r_i, r_m | r_m < \delta)}{var(r_m | r_m < \delta)}, \end{aligned} \tag{1}$$

where r_i is the log excess return of asset i over the risk-free rate, r_m is the log market excess return, β_i and β_i^- are the unconditional and downside beta defined by an exogenous threshold (δ) for the market return, and λ and λ^- are the unconditional and downside prices of risk, respectively. This empirical framework is flexible in allowing variations both in the quantity and the price of risk while maintaining a parsimonious parametrization with a single threshold δ.

Note that the model reduces to the CAPM in the absence of differential pricing of downside risk from unconditional market risk: $\lambda^- = 0$; or if the downside beta equals the CAPM beta: $\beta_i^- = \beta_i$. As in the case of the CAPM, the model also restricts the unconditional price of risk to equal the expected market excess return:

$$E[r_m] = \lambda, \tag{2}$$

because both the unconditional and downside beta of the market with itself are equal to 1.

To clarify the terminology used in this paper, notice that we employ the concept of *conditionality* in the context of *contemporaneous* realizations of states of the world: market return above or below a threshold. A part of the asset pricing literature has instead applied similar terminology in the context of time variation of expected returns and return predictability tests.

We stress that while we do not allow for time variation in the betas or the prices of risk, our empirical methodology is consistent with some predictability in expected returns. Since we test our model on sorted portfolios that capture a characteristic associated with expected returns, for example the interest rate differential, we allow for predictability generated by variation over time in this characteristic. Cochrane [17] notes the similarity between testing the model on sorted portfolios and testing the model on unsorted assets while allowing for time variation in instruments that proxy for managed portfolios. Our procedure, however, does not allow variation in expected returns through time for a fixed characteristic.

For example, we capture the fact that the expected return for a specific currency pair varies through time as the corresponding interest rate differential varies, but we do not allow for the expected return of a specific currency pair to vary through time given a constant interest rate differential. Lustig et al. [35] similarly allow predictability only through variation in the interest rate differential.[7]

Finally, our model specification is similar to the one tested by Ang et al. [2] on equity portfolios. While the present specification has the convenience of both nesting the CAPM and reducing the number of estimated coefficients in the cross-sectional regression to the price of downside risk λ^-, we report in the appendix the estimates for the specification in Ang et al. [2] for our benchmark test assets.

2.1. Data

We use the bilateral currency returns dataset in Maggiori [38]; details of the data are included in the online appendix and in the original reference. The data are monthly, from January 1974 to March 2010, and cover 53 currencies. We follow Lustig and Verdelhan [36] in defining a cross section of currency returns based on their interest rate. We sort currencies into 6 portfolios, in ascending order of their respective interest rates.

Since the dataset includes currencies for which the corresponding country has undergone periods of extremely high inflation and consequently high nominal interest rates, we split the sixth portfolio into two baskets: 6A and 6B. Portfolio 6B includes currencies that belong to portfolio 6 and that have annualized inflation at least 10% higher than US inflation in the same month.[8]

We also use an alternative sorting that only includes developed countries' currencies.[9] In this case we sort the currencies into 5 rather than 6 baskets, to take into account the overall reduced number of currencies.

We calculate one-month bilateral log excess returns r_{t+1} as the sum of the interest differential and the rate of exchange rate depreciation of each currency with the US dollar:

$$r_{t+1} = i_t^\star - i_t - \Delta s_{t+1},$$

where i^* and i are the foreign and US interest rate, and s_t is log spot exchange rate expressed in foreign currency per US dollar.

Figure 2 shows that the sorting produces a monotonic increase in returns from portfolios 1 to 6. Further descriptive statistics are reported in Table 1. Portfolios 6A and 6B highlight the very different behavior of high inflation currencies. The standard deviation of returns for portfolio 6B is almost double that of all other baskets. Bansal and Dahlquist [4] note that the uncovered interest parity condition cannot be rejected for these currencies.

[7] It is in principle possible to allow both the concept of conditionality used in this paper and the time variation in betas and prices of risk to co-exist within the same model. In the present context, this could be achieved by estimating time varying betas and lambdas. Since this would require extracting additional information from a potentially limited number of observations for the downstate, we opted to impose constant betas and lambdas through time. While we do not disregard the possibility of time varying parameters, we view our model choice as conservative given the available data and stress that this restriction is routinely imposed on asset pricing models especially when testing them on sorted portfolios.

[8] We view our results excluding the high inflation currencies as conservative since these noisy observations are eliminated. Our results are robust to different threshold levels or to the inclusion of all the currencies in the 6th portfolio. The inflation data for all countries is from the IMF International Financial Statistics.

[9] A country is considered developed if it is included in the MSCI World Equity Index.

These findings and the general concern about the effective tradability of these currencies during periods of economic turmoil lead us to present our benchmark results using only basket 6A and to provide robustness checks including both basket 6 and 6B in the online appendix.

For our benchmark results on the cross section of equity returns we use the six Fama & French portfolios sorted on size and book-to-market for the period from January 1974 to March 2010. In additional results we also test our model on the cross section of industry-sorted equity portfolios by Fama & French for the period from January 1974 to March 2010, on the CAPM-beta sorted equity portfolios of Frazzini and Pedersen [27] for the period from January 1974 to March 2010, and on the equity index option return series by Constantinides, Jackwerth, and Savov [20] for the period from April 1986 to March 2010.

For the cross section of commodity returns we use five commodity-futures portfolios sorted by the commodity basis for the period from January 1974 to December 2008 by Yang [46]. For the cross section of sovereign bonds we use six sovereign-bond portfolios sorted by the probability of default and bond beta for the period from January 1995 to March 2010 by Borri and Verdelhan [6].

For the "market" return we use the value-weighted CRSP US equity market log excess return for the period January 1974 to March 2010. We use a broad US equity market return as the market return in our benchmark results not only because it is the most commonly used return to test CAPM-like asset pricing models, but also to conservatively avoid increasing the covariances between test assets and pricing factors by including our other test assets, such as currencies and commodities, in our market index. Nonetheless, in robustness checks included in the appendix we repeat our benchmark analysis using the MSCI World Market Equity Index returns and our own "market index" built by merging all our test assets in a single index.

Tables 2 and 3 provide summary statistics for the equity, equity index options, commodity futures and sovereign bond portfolios returns. In Table 2, Panel A highlights the pattern that small and value stocks have higher returns; Panel B highlights that futures on commodities that have low basis have higher returns; Panel C highlights that sovereign bonds have higher returns whenever they have lower credit rating and/or higher CAPM betas. In Table 3, Panel A highlights that equities that have high preformation CAPM-betas tend to earn (somewhat) lower returns; Panel B creates a cross section by sorting equities on their industry classification; Panels C and D show that portfolios that are short equity index put options and long call options earn higher returns the further the options are out of the money and the shorter (longer) the maturity for puts (calls).

2.2. Conditional Correlations

The central insight underlying our work is that the currency carry trade, as well as other cross-sectional strategies, is more highly correlated with aggregate market returns conditional on low aggregate returns than it is conditional on high aggregate market returns. This insight is supported by a growing empirical literature including Brunnermeier, Nagel, and Pedersen [7], Burnside [8], Lustig and Verdelhan [37], Christiansen, Ranaldo, and Soederlind [16], Mueller, Stathopoulos, and Vedolin [42] all of which find a state dependent correlation. In ongoing work, Caballero and Doyle [14] and Dobrynskaya [22] highlight the strong correlation of the carry trade with market risk during market downturns. Our paper differs from all previous studies both by providing systematic evidence over a longer time period and larger sample of this state dependent correlation and by relating the resulting downside risk to that observed in other asset classes such as equities, equity index options, commodities, and sovereign portfolios.

We define the downstate to be months where the contemporaneous market return is more than one standard deviation below its sample average. A one standard deviation event is a reasonable compromise between a sufficiently low threshold to trigger concerns about downside risk and a sufficiently high threshold to have a large number of downstate observations in the sample. Our definition assigns 55 monthly observations to the downstate, out of 435 total observations in our sample. For robustness we test our model with different threshold levels as well as a finer division of the state space into three rather than two states.[10]

Table 4 shows that the carry trade is unconditionally positively correlated with market returns. As reported in the third row of the table, the unconditional correlation is 0.14 and statistically significant for our benchmark sample of currencies. Most of the unconditional correlation is due to the downstate: conditional on the downstate the correlation increases to 0.33, while it is only 0.02 in the upstate.[11] The table also confirms that this pattern is robust to the exclusion of emerging markets and to various thresholds of inflation for the basket 6B.

Figure 3 highlights this characteristic of the data by plotting the kernel-smoothed conditional correlation between the carry trade and the market returns. The top panel shows that the correlation of high yield currencies with the market returns is a decreasing function of market returns. The opposite is true for low yield currencies in the middle panel. The bottom panel highlights that our results are not sensitive to the exact choice of threshold.

3. Econometric Model

We estimate the model in (1) with the two-stage procedure of Fama and MacBeth [24]. In our model the first stage consists of two time-series regressions, one for the entire time series and one for the downstate observations. These regressions produce point estimates for the unconditional and downstate betas, $\hat{\beta}$ and $\hat{\beta}^-$, which are then used as explanatory variables in the second stage. The second-stage regression is a cross-sectional regression of the average return of the assets on their unconditional and downstate betas. In our estimation we restrict, following the theory section above, the market price of risk to equal the sample average of the market excess-return. Therefore, in the second-stage regression we estimate a single parameter: the downside price of risk λ^-.

[10] Thresholds of the sample average minus 0.5 or 1.5 standard deviations assign 118 observations and 27 observations to the downstate, respectively.

[11] The upstate includes all observations that are not included in the downstate.

Formally, the first-stage regressions are:

$$
\begin{aligned}
r_{it} &= a_i + \beta_i r_{mt} + \epsilon_{it}, \qquad \forall t \in T, & (3)\\
r_{it} &= a_i^- + \beta_i^- r_{mt} + \epsilon_{it}^-, \qquad \text{whenever} \quad r_{mt} \leqslant \bar{r}_m - \sigma_{r_m}, & (4)
\end{aligned}
$$

where $\bar{r}_m$ and σ_{r_m} are the sample average and standard deviation of the market excess return, respectively. The second-stage regression is given by:

$$
\bar{r}_i = \hat{\beta}_i \bar{r}_m + (\hat{\beta}_i^- - \hat{\beta}_i)\lambda^- + \alpha_i, \quad i = 1, \ldots, N, \tag{5}
$$

where $\bar{r}_i$ and $\bar{r}_m$ are the average excess returns of the test assets and the market excess-return respectively, α_i are pricing errors, and N is the number of test assets. Notice that by not including a constant in the second-stage regression we are imposing that an asset with zero beta with the risk factors has a zero excess return.[12]

While restricting the model so that the market return is exactly priced reduces the number of coefficients to be estimated in the cross-sectional regression, it does not imply that the sample average market return is estimated without noise. The average monthly log excess return of the value-weighted CRSP US equity market for the sample period from January 1974 to March 2010 is 0.39% with a standard error of 0.23%.[13] This corresponds to an annualized log-excess return for the market of 4.68%, an estimate in the range of the values usually assumed to calibrate the equity premium. To make clear that the unconditional market price of risk is imposed rather than estimated in our cross-sectional regressions, we report its estimate with a star and do not report its standard error in all tables of the paper. While restricting the market to be exactly priced is regarded as a conservative procedure, we report in the appendix our benchmark results for currencies, commodities and equities without imposing this restriction and note that in that case we recover an estimate of the price of unconditional market risk of 0.29 that is similar to the sample average estimate of 0.32.

4. Empirical Results

4.1. Risk Premia: Currency

We find that while the CAPM shows that currency returns are associated with market risk, it cannot explain the cross section of currency returns because the CAPM beta is not sufficient to explain the cross sectional dispersion in returns. The left panel of Figure 4 shows that the increase in CAPM beta going from the low yield portfolio (portfolio 1) to the high yield portfolio (portfolio 6) is small compared to the increase in average returns for these

[12] In unreported results we estimated the model including a constant in the cross-sectional regression and verified that the constant is not statistically significant.

[13] When estimating the model on sub-periods, we always impose that the average market return over that sub-period is priced exactly by correspondingly adjusting the value of λ.

portfolios. As it will shortly become evident, once the market price of risk of CAPM is pinned down by the average market excess return, the CAPM fails to price these currency portfolios.

The middle panel of Figure 4 shows that average currency returns are also strongly related to the downstate beta. While this finding supports the importance of downside risk for currency returns, it is not per se evidence of a failure of the CAPM because currencies that have a higher downstate beta do have a higher CAPM beta.

However, the right panel of Figure 4 shows that the relative downstate beta, the difference between downstate and unconditional beta, is also associated with contemporaneous returns. Currencies that have higher downstate than unconditional betas are on average riskier and earn higher excess returns. We show in our benchmark regressions that this state dependency is not fully captured by the CAPM beta.

Figure 5 and Table 5 illustrate both the failure of the CAPM and the performance of the DR-CAPM. The top panels of Figure 5 present the results employing all currencies, the bottom panels present the results employing only currencies of developed countries. Since higher yield currencies have higher CAPM betas, they earn a higher return on average. However, the CAPM beta does not fully capture the risk-return tradeoff: the spread in betas is too small to account for the spread in currency returns. The failure is evident in the first column of Table 5, where the CAPM cannot jointly price the market return and the cross section of currency returns producing a R^2 of only 9%.[14] Correspondingly, the left panels of Figure 5 show that the CAPM predicts almost identical returns for all currency portfolios.

In contrast, the DR-CAPM explains the cross section of currency returns. In the second column of Table 5, the DR-CAPM explains 79% of the cross-sectional variation in mean returns even after imposing the restriction that the market portfolio (included as a test asset) is exactly priced. The right quadrants of Figure 5 correspondingly show that the test assets lie close to the 45 degree line. The estimated price of downside risk is positive (2.18) and statistically significant.[15] The model fits the returns of portfolios 2 to 6A with small pricing errors. The absolute pricing error is on average 0.07% (in terms of monthly excess returns) across these portfolios. Portfolio 1, which contains the low yield currencies, is priced with the biggest pricing error, -0.2%.[16] We also report the χ^2 test that all pricing errors in the cross-sectional regression are jointly zero. While both the CAPM and the DR-CAPM are formally rejected with p-values of 0% and 0.04% respectively, we stress that the DR-CAPM produces a root mean square pricing error (RMSPE) that is 40% smaller than that of the CAPM.[17]

[14]We define the cross-sectional R^2 as: $R^2 \equiv 1 - \hat{\alpha}'\hat{\alpha}[N\ Var(r)]^{-1}$, where $\hat{\alpha}$ is the vector of pricing errors, $Var(r)$ is the variance of the vector of test assets mean returns, and N is the number of test assets.

[15]The Fama MacBeth procedure does not automatically correct the second-stage regression standard errors for estimated regressors from the first-stage. Given our separate first-stage regressions for the full sample and the downstate, the Shanken correction (Shanken [45]) is not immediately applicable here. In the robustness section of this paper and in the appendix, we provide a number of checks of the standard errors to minimize concerns about their reliability.

[16]Note that the pricing errors here and in all subsequent tables and references in the text are expressed in monthly percentage excess returns, while the figures are annualized percentage excess returns. The pricing errors are defined as the difference between the actual and model-predicted excess return, so that a positive price error corresponds to an under prediction of the return by the model.

[17]The test is under the null hypothesis of zero joint pricing errors, therefore the model is not rejected at the 5% confidence level if the p-value statistic is higher than 5%.

Potential sources of concern about the reliability of our currency returns are sovereign default and international capital restrictions. To alleviate these concerns, we test the DR-CAPM on a subsample of developed countries' currencies. The results for this subsample of countries are also reported in Figure 5 and Table 5 and show that the model performs equally well on these portfolios. The price of downside risk is 2.34 and is consistent with the 2.18 estimate obtained on the full sample. The R^2 increases to 85%. We confirm on this subsample the pattern of small DR-CAPM pricing errors for all portfolios except portfolio 1. The null hypothesis of zero joint pricing errors cannot be rejected at the 5% confidence level with a p-value of the χ^2 test of 8%. The RMSPE of 0.07 is more than 50% smaller than the one produced by the CAPM on the same test assets.

4.2. Risk Premia: Other Asset Classes

The conditional association of asset returns and the market portfolio and the variation in prices of risk is not unique to currencies and is, in fact, shared by other asset classes. Providing a unified risk-based treatment of expected returns across asset classes is both informative from a theoretical perspective and an important check of the empirical performance of theoretical models.

Figure 6 shows that equity, commodity, and sovereign bond portfolios' expected returns are positively related to these assets' relative downside betas. In all three asset classes, assets that are more strongly associated with market returns conditional on the downstate than unconditionally have higher average excess returns. This conditional variation – which is not captured by the CAPM – is the central mechanism that underlies the performance of the DR-CAPM across asset classes.

We investigate next whether the DR-CAPM can jointly explain the cross section of currency and equity returns. We add the six Fama & French portfolios sorted on book-to-market and size to the currency and market portfolios as test assets. Figure 7 and Table 5 show that the DR-CAPM jointly explains these returns. The last column in Table 5 shows that the estimated price of downside risk is consistent across asset classes but the estimate of 1.41 is lower than that obtained on currencies alone (2.18).[18] The model explains 71% of the observed variation in mean returns, a noticeable increase over the 24% explained by the CAPM. Figure 7 shows that the largest pricing errors occur for the small-growth equity portfolio (portfolio 7) in addition to the low-yield currency portfolio (portfolio 1). The average absolute pricing error on all other portfolios is 0.08%, while the pricing errors on the small-growth equity portfolio and the low-yield currency portfolios are -0.2% and -0.47%, respectively. Section 6.6.2 provides further details about the pricing of the small-growth equity portfolio. Both the CAPM and the DR-CAPM are statistically rejected with p-values of the χ^2 test of 0%, but the DR-CAPM produces a RMSPE 40% smaller than the CAPM.

A close analog to the currency carry trade is the basis trade in commodity markets. The basis is the difference

[18] If the small-growth equity portfolio is excluded as a test asset, the estimated price of risk increases to 1.70.

between the futures price and the spot price of a commodity. Among others, Yang [46] shows that commodities with a lower basis earn higher expected returns (see Table 2 Panel B).[19] We extend our results by adding the commodity portfolios to the currency and equity portfolios. Figure 8 and Table 6 show that the same economic phenomenon, the conditional variation of the quantity and price of market risk, underlies the variation in expected returns in commodity markets. The fourth column in Table 6 shows that the estimated price of downside risk (1.40) is essentially unchanged after the addition of the commodity portfolios to the currency and equity portfolios studied above and is statistically significant. The model explains 74% of the cross sectional variation in returns across these asset classes compared to a R^2 of -17% for the CAPM. The biggest pricing error occurs for the high-basis commodity portfolio (portfolio 11) in addition to the low-yield currency portfolio (portfolio 1) and the small-growth equity portfolio (portfolio 12). The pricing errors for these three portfolios are -0.24%, -0.22%, and -0.46%, respectively. The average absolute pricing error of all other portfolios included as test assets is 0.07%. While both the CAPM and the DR-CAPM are again statistically rejected, the DR-CAPM produces a RMSPE 50% smaller than the CAPM.

We investigate next whether sovereign bonds are priced by the DR-CAPM. We use the cross-sectional sorting of sovereign bonds according to default probability and market beta in Borri and Verdelhan [6]. Figure 9 and Table 7 confirm yet again the ability of the DR-CAPM to price multiple asset classes. An important caveat in this case is that the data of Borri and Verdelhan [6] are only available over a relatively short sample period (January 1995 to March 2010), thus limiting the number of observations, particularly for our downstate. The shorter sample produces noisier estimates of the prices of risk and different point estimates overall from our full sample. The sample limitations impose caution in interpreting the positive performance of our model on sovereign bonds. Consequently, we exclude these portfolios from the analysis in the rest of the paper.

In our benchmark results for equity markets we employ the Fama & French book-to-market and size sorted portfolios because they are among the most commonly tested equity cross sections. In addition, we document here that the DR-CAPM can rationalize a number of other important cross sections in equity markets: the CAPM-beta sorted cross section, the industry sorted cross section, and the equity index options cross section.

In Figure 10 and Table 7 we analyze the performance of the DR-CAPM for the cross section of CAPM-beta sorted equity portfolios of Frazzini and Pedersen [27] as well as for their "Betting Against Beta" (BAB) factor for equity markets.[20] The DR-CAPM has higher explanatory power than the CAPM for the joint cross section of currency, commodity and beta-sorted equity returns with estimates of the market price of downside risk consistent with those estimated on other cross sections. Notably the BAB factor has a 1.03% pricing error under the CAPM that is almost seven times bigger than the 0.15% pricing error under the DR-CAPM.

[19] Also see Gorton, Hayashi, and Rouwenhorst [28].

[20] The BAB factor is built via a long position in low beta equities and a corresponding short position in high beta equities. See original reference for details.

We have documented that for the cross-section of currencies, commodities and Fama & French portfolios the CAPM under-predicts the returns and the downside risk factor is able to fill the gap between the CAPM predicted returns and the actual returns in the data. Interestingly, for the beta-sorted portfolios CAPM over-predicts the returns of the high-beta portfolios with respect to the low beta portfolios; a fact that Frazzini and Pedersen [27] refer to as a "too flat" Capital Market Line in the data. The DR-CAPM in part corrects the over-prediction of the CAPM because high-beta equities have a relatively lower downside risk exposure compared to low-beta equities. For example, consider the BAB factor in the top panels of Figure 10: by construction it has a CAPM beta close to zero, estimated at -0.05 and not statistically significant, and its riskiness is entirely captured by its downside beta, estimated at 0.48 and statistically significant (see Panel A Table 10).[21] Therefore, for the BAB portfolio the CAPM implies an annualized expected excess return of -0.19%, while the DR-CAPM predicts a return of 10.3% which is substantially closer to the actual average return of 12.13%.[22] This result is consistent with the analysis in Frazzini and Pedersen [27] who note that the BAB factor performs particularly poorly when the overall market return is low, thus naturally generating a downside risk exposure.

In Figure 11 and Table 7 we test the DR-CAPM on the industry-sorted equity portfolios of Fama & French jointly with the currency and commodity portfolios. We consistently find that the DR-CAPM can rationalize these test assets with a price of downside risk, here estimated at 1.36, similar to that estimated on other cross-sections. The last column in Table 7 shows that the model explains 75% of the joint variation in returns of currencies and equity industry portfolios with a substantial increase over the -32% explained by the CAPM.

Finally, we investigate whether the DR-CAPM can rationalize option returns. Options, and in particular portfolios short in put options written on the market index, are naturally exposed to downside risk. We test the model on the cross-section of equity index (S&P 500) option returns in Constantinides et al. [20].[23] Figure 12 and Table 8 present the results based on the cross-section of call and put options. The second column in Table 8 shows that the DR-CAPM not only captures 81% of the variation in expected returns across option portfolios, but can also jointly rationalize this variation together with the returns of currencies and commodities (R^2 of 74%, see column four of the same table). This further confirms that the estimated value of the price of downside risk (λ^-) is consistent across asset classes even when considering optionality features.

In contrast, the CAPM cannot rationalize option returns. By construction the option portfolios have a CAPM beta close to 1 (see Panels C-D Table 10), thus generating almost identical CAPM-predicted returns for all portfolios, but have substantial variation in realized average excess returns (close to a 25% range).[24] Almost all option

[21] Frazzini and Pedersen [27] build the BAB factor to have zero CAPM beta. Small differences in the beta occur here because of the use of a different index to proxy for the CAPM market portfolio as well as a different time period.

[22] The CAPM prediction is obtained by multiplying the beta times the market price of risk (-0.05*0.32*12=-0.19). Similarly the DR-CAPM prediction is obtained by summing to the CAPM prediction the downside risk correction of $(\beta^- - \beta)\lambda^- * 12 = (0.48 + 0.05)1.65 * 12 = 10.49$.

[23] The cross section includes 18 portfolios of calls (9) and puts (9) sorted on maturity and in-the-moneyness. See original source for portfolio construction details.

[24] Recall that Constantinides et al. [20] build the option portfolios by imposing that under the Black and Scholes assumptions they

portfolios are accurately priced with small pricing errors with the exception of the 30-day maturity and 90% moneyness put portfolio.[25] Constantinides et al. [20] report that this portfolio is hard to price even for most option-market-tailored asset pricing models and consider the possibility that liquidity issues might affect its pricing.

We have shown that the DR-CAPM can rationalize a number of important asset classes and that the estimate of the price of risk remains stable across different estimations. While this reduces concerns about the reliability of estimates of λ^{-}, further quantitative implications of our empirical framework, for example about the magnitude of λ^{-}, cannot be drawn without imposing a more structural theory on the model. We leave the development of a structural theory to future work and only note here that λ^{-} is consistently estimated across a number of different cross sections, asset classes and patterns in expected returns.[26]

5. Robustness

An important verification of our results is to confirm the association of currency returns with downside market risk. In Panel A of Table 9 we provide the first-stage estimates of the unconditional CAPM betas and the downstate betas for the six currency portfolios. The CAPM betas are increasing from portfolio 1 to 6 and the spread in betas between the first and last portfolio is statistically different from zero. The increase in betas, however, is small; the beta of the first portfolio is 0.03 while the beta of the last portfolio is 0.11. The downstate betas highlight the central mechanism of the DR-CAPM: conditional on below-threshold market returns, high yield currencies (portfolio 6A) are more strongly related to market risk than low yield currencies (portfolio 1). In fact, we find that while the downside beta of portfolio 6A (0.30) is larger than its unconditional beta (0.11), the opposite is true for portfolio 1 with a downside beta of 0.02 and an unconditional beta of 0.03.

Splitting the sample into the downstate picks up the conditional variation in currencies' association with market risk, but also reduces the variation available in each subsample to estimate the betas. Therefore, the standard errors of the first-stage regressions that estimate downstate betas are wider than those of the corresponding regressions for unconditional betas. We perform a number of robustness checks of our first-stage estimates and their impact on the second-stage estimates.

We perform two bootstrap tests to check the robustness of the main driver of our results: the different conditional association of high yield and low yield currencies with the market excess-return. We first test whether high yield currencies are more associated with market risk than low yield currencies conditional on the downstate under the null hypothesis that $\beta^{-}_{6A} - \beta^{-}_{1} = 0$. We then test whether the different loading on risk of high and low yield

would have a CAPM beta of 1 with the $S\&P$ 500 index. The variation in CAPM betas reported here with respect to the original source is due to the use of the value-weighted CRSP as a market index as well as a different time period for the sample.

[25] This is the shortest maturity and furthest out of the money portfolio in the sample.

[26] Ultimately, the quantitative importance of downside risk can also be linked to the rare disasters model of Barro [5]. Farhi and Gabaix [26] develop a model of exchange rates in the presence of rare disasters and Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan [25] and [31] evaluate rare disasters in currency markets in an option framework.

currencies varies across states under the null hypothesis that $(\beta^-_{6A} - \beta^-_1) - (\beta_{6A} - \beta_1) = 0$. Figure 14 shows that both nulls are strongly rejected with p-values of 0.26% and 2.47%, respectively, thus yielding statistical support for our main economic mechanism.

A second robustness check is to mitigate the concern that our second-stage regression employs potentially weak estimated regressors from the first stage. Panel B in Table 9 reports the first-stage estimates for the six Fama & French equity portfolios. Since these equity portfolios have a strong association with the overall equity market, the betas are very precisely estimated even for the downstate. We then use the prices of risk estimated using only these equity portfolios to fit the cross section of currencies. Table 11 reports in the first two columns that the DR-CAPM can still explain 67% of the observed variation in currency returns and 71% of the variation in currency and equity returns. The estimated price of downside risk is 1.27, statistically significant, and consistent with the estimate of 1.41 obtained on the joint sample of currencies and equities.[27]

In the middle two columns of Table 11 we verify that our results are not altered by reasonable variations in the threshold for the downstate. We vary our benchmark threshold for the market return of 1 standard deviation below its sample mean to 0.5 and 1.5 standard deviations. In both cases we observe a consistent performance of the model.

Finally, we verify the sensitivity of our results to different thresholds for excluding currencies with high inflation. We vary the inflation threshold from our benchmark of 10% above the annualized inflation of the US to 5% and 15%. The last two columns of Table 11 show that the lower threshold produces higher but noisier estimates of the price of risk compared to the higher threshold. In both cases, however, the prices of risk are statistically significant and the R^2 are around 80%.

Further robustness checks are provided in the online appendix. We verify that our results are robust to: using only developed countries' currencies, winsorizing the data, varying the inflation threshold for the last currency portfolios, not imposing the restriction that the market return be exactly priced in sample, alternative measures of the market index, estimating the model on a longer sample (and relative subsamples) for equity markets, and to using the model specification in Ang et al. [2].

6. Factor Structure and PCA Based Models

To further investigate the common factor structure in the joint cross-section of currencies, equities, and commodities we perform a principal component analysis (PCA) both on each asset class separately and on their joint returns. This analysis allows us to compare the DR-CAPM to the asset class-specific PCA-based models that are prevalent in the literature.

[27] This robustness check also minimizes concerns about the reliability of second-stage Fama-MacBeth standard errors due to the presence of estimated regressors. Our results are little changed when employing first stage estimates that are very accurate.

6.1. Currency PCA Model

For currencies, the PCA analysis leads to the model of Lustig et al. [35]. Consistent with their work, we report in Panel A of Table 12 that the first two principal components account for 87% of the time series variation of the interest-rate-sorted currency portfolios. The loadings of the first principal component reveal that it can be interpreted as a level factor because it loads on the returns of all currency portfolios similarly. Analogously, the loadings of the second principal component reveal that it can be interpreted as a slope factor because it loads on the differential return when going from portfolio 1 to portfolio 6A. Intuitively, these two principal components can be approximated by two portfolios: an equally weighted portfolio of all currencies in the sample against the dollar and a carry trade portfolio created by a long position in portfolio 6 and a short position in portfolio 1. We refer to these two portfolios as the dollar and carry portfolios, and denote their returns by RX_{cur} and HML_{cur} respectively. To confirm the intuition, Table 13 reports in the top left panel that the correlation between the first principal component and the dollar portfolio is 100% and the correlation between the second principal component and the carry portfolio is 95%.

Table 14 presents the estimates of both the PCA-based linear model of Lustig et al. [35] and the DR-CAPM on the cross-section of currency returns. The LRV model explains 64% of the cross sectional variation in currency returns. The estimated price of risk is statistically significant for the carry portfolio but not for the dollar portfolio. The model is statistically rejected by the χ^2 test on the pricing errors with a p-value of 0%. Notice that it is the slope factor, the carry portfolio, that carries most of the information relevant for the cross section. A model that only includes the first principal component, the level factor or dollar portfolio, generates a R^2 of only 4%. Similarly to the DR-CAPM, the largest individual pricing error (-0.2%) for the LRV model is for the low-yield currency portfolio (portfolio 1).

The DR-CAPM captures the information contained in the principal components that is relevant for this cross section. Intuitively, the DR-CAPM summarizes the two principal components because the unconditional market return acts as a level factor while downside risk acts as a slope factor. To confirm this intuition, recall from Table 9 Panel A that the unconditional market betas are relatively similar across currency portfolios, so that all portfolios load similarly on the market. In contrast, the downside betas are more strongly increasing going from portfolio 1 to portfolio 6, thus providing a slope factor. The top two panels in Table 13 confirm that the second principal component (or the carry portfolio) is more highly correlated with the market portfolio in downstates (28% correlation), thus loading on downside risk, than it is unconditionally (9% correlation). The DR-CAPM produces a R^2 of 73% and RMSPE of 0.10 that are similar to the R^2 of 64% and RMSPE of 0.12 of the LRV model.

6.2. Equity PCA model

The PCA on the cross-section of equities provided by the six Fama & French portfolios sorted on size and book-to-market leads to the three factor model of Fama and French [23]. Panel B in Table 12 shows that the first three principal components account for 98% of the time series variation of the size and book-to-market sorted portfolios. The loadings of the first principal component reveal that it can be interpreted as a level factor because it loads on the returns of all equity portfolios similarly. The loadings of the second and third principal components reveal that they can be interpreted as two slope factors. The second principal component mainly loads on the differential return when going from small portfolios (1 to 3) to big portfolios (4 to 6). The third principal component mainly loads on the differential return when going from growth portfolios (1 and 4) to value portfolios (3 and 6). However, notice that the interpretation is not as clear as it is for currencies (nor as it is for commodities below). For example, the third principal component does not affect portfolio 2 and 5 in a way consistent with its interpretation as a factor affecting the value-growth trade-off in returns.

We approximate the first principal component with the market return and the next two principal components by the Fama & French factors: the small-minus-big portfolio and the high-minus-low portfolio. We denote the returns of these two portfolios as SMB and HML_{ff}, respectively. Table 13 shows in the middle left panel that the first principal component is highly correlated with the market (95% correlation), the second principal component is mainly related to the SMB return (80% correlation), and the third principal component is mainly related to the HML_{ff} return (82% correlation). However, HML_{ff} and SMB returns are themselves correlated and therefore do not correspond exactly to the two principal components that are by construction orthogonal to each other. Correspondingly, we find that HML_{ff} is also correlated with the second principal component and SMB is correlated with the third principal component.[28]

Table 15 presents the estimates of both the PCA-based linear model of Fama and French [23] and the DR-CAPM on the cross section of equity returns. The Fama & French three factor model explains 68% of the cross sectional variation in returns. The estimated prices of risk are significant for the market and HML_{ff} but not for SMB. The model is statistically rejected by the χ^2 test on the joint pricing errors with a p-value of 0%. Notice that the cross-sectional performance of the model is driven by the third principal component, which is approximated by the HML_{ff} factor. A model based only on the first two principal components generates a R^2 of -4%.

The DR-CAPM is unable to match the small-growth equity returns of portfolio 1 (pricing error of -0.45%) and therefore produces a lower R^2 (33%) than the Fama & French three-factor model. As noted by Campbell and Vuolteenaho [15], it is typical in the literature to find that models cannot correctly price portfolio 1 and a number of papers (Lamont and Thaler [33], D'Avolio [21], Mitchell, Pulvino, and Stafford [41]) have questioned whether its return is correctly measured.[29] In the last column of Table 15 we show that once we remove portfolio 1 from the

[28] The correlation between HML_{ff} and SMB helps to rationalize why the interpretation of the equity principal components in terms of mimicking portfolios is not as clear as it is for currencies or commodities. In the case of currencies and, as will shortly be illustrated, in the case of commodities, the proxy portfolios of the two principal components are themselves almost uncorrelated. For example, the correlation between RX_{cur} and HML_{cur} is only 0.07.

[29] Note that these papers refer to portfolio 1 as the small-growth portfolio in the 25-portfolio sorting of Fama & French, while our first portfolio is the small-growth portfolio in the 6-portfolio sorting of Fama & French. Our first portfolio, therefore, includes more securities than those considered troublesome in the cited papers. In the appendix, however, we verify that the DR-CAPM mispricing of the first portfolio in our setting is due to the securities that are part of the smallest growth portfolios in the 25-portfolio sorting.

six Fama & French portfolios the DR-CAPM performance improves: the R^2 increases to 90% and the hypothesis of zero joint pricing errors cannot be rejected by the χ^2 test at the 5% confidence level.

6.3. Commodity PCA model

The PCA on the cross-section of commodities leads to the model of Yang [46]. Consistent with his work, we report in Panel C in Table 12 that the first two principal components account for 75% of the time series variation of the basis-sorted commodity portfolios. The loadings of the first principal component reveal that it can be interpreted as a level factor because it loads on the returns of all commodity portfolios similarly. Analogously, the loadings of the second principal component reveal that it can be interpreted as a slope factor because it loads on the differential return when going from portfolio 1 to portfolio 5. Intuitively, these two principal components can be approximated by two portfolios: an equally weighted portfolio of all commodities contained in the sample and a basis trade portfolio created by a long position in portfolio 1 and a short position in portfolio 5. We refer to these two portfolios as the commodity and basis portfolios and denote their returns by RX_{com} and HML_{com}, respectively. To confirm this intuition, the bottom left panel of Table 13 shows that the correlation between the first principal component and the commodity portfolio is 100% and the correlation between the second principal component and the basis portfolio is 95%.

Table 16 presents the estimates of both the PCA-based linear model of Yang [46] and the DR-CAPM on the cross-section of currency returns. The Yang model explains 87% of the cross sectional variation in expected returns. The estimated price of risk is statistically significant for both the commodity and basis portfolios. The hypothesis of zero joint pricing errors cannot be rejected by the χ^2 test with a p-value of 50%. Notice that it is the slope factor, the basis portfolio, that carries most of the information relevant for the cross section. A model that only includes the first principal component, the level factor or commodity portfolio, generates a R^2 of only 10%.

The DR-CAPM captures the information contained in the principal components that is relevant for this cross section. Intuitively, the DR-CAPM summarizes the two principal components because the unconditional market return acts as a level factor, while downside risk acts as a slope factor. To confirm this intuition, recall from Table 9 Panel C that the unconditional market betas are similar across commodity portfolios, so that all portfolios load similarly on the market, while the downside betas are decreasing when going from portfolio 1 to portfolio 5, thus providing a slope factor.[30] The bottom two panels in Table 13 confirm that the second principal component (or the basis portfolio) is more highly correlated with the market portfolio in down states (19% correlation), thus loading on downside risk, than it is unconditionally (−5% correlation). The DR-CAPM produces a R^2 of 82% and RMSPE of 0.12 that are similar to the R^2 of 87% and RMSPE of 0.10 of the Yang model. The hypothesis that the DR-CAPM pricing errors are jointly zero cannot be rejected by the χ^2 test with a p-value of 66%.

Our results, therefore are consistent with the previous evidence on small-growth stocks.

[30] Notice that for commodity portfolios the unconditional betas are almost increasing when going from portfolio 1 to portfolio 5, but the effect is quantitatively small and dominated by the more strongly decreasing downside betas.

Having investigated the factor structure of each asset class separately, we conclude that for each asset class the DR-CAPM has similar explanatory power to the PCA-model that is specifically designed for that asset class.[31] We emphasize that the underlying reason is that in each asset class the factor structure is composed of level and slope factors that the DR-CAPM picks up with the market and downside risk factors, respectively.

6.4. PCA models across asset classes

We now turn to investigate the factor structure of the joint cross section of currencies, equities, and commodities. Figure 15 plots together the loadings of the principal component analysis performed on each asset class separately. The left panel suggests that the first principal component in each asset class represents a joint level factor. The right panel shows that the subsequent principal components of each asset class are common slope components.

Tables 17 and 18 explore the predictive power of the PCA-based models analyzed above and the DR-CAPM across asset classes. Table 17 estimates the models using the proxy portfolios, while Table 18 employs directly the principal components. Each of the asset-class-specific models is unable to price the joint cross section. Both the LRV model and the Yang model have negative R^2 (-15% and -35%, respectively) and the Fama & French model has a modest R^2 of 35%. The LRV model estimates a significant price of risk for the carry portfolio and the estimate increases to 0.99 from the 0.47 estimate obtained when using only currency portfolios as test assets. The price of risk of the dollar portfolio remains statistically insignificant. The Yang model estimates a significant price of risk for the commodity portfolio but not for the basis portfolio. The Fama & French model estimates a significant price of risk only for the HML_{ff} portfolio. The point estimates for the prices of risk of the market, SMB, and HML_{ff} portfolios are 0.28, 0.23, and 0.57, respectively; these point estimates are overall comparable to the 0.36, 0.19, and 0.49 estimates obtained when using only the equity portfolios as test assets. The failure of asset-class specific models to price other asset classes has induced a search for segmented theoretical models that could explain why different stochastic discount factors are needed to price different asset classes. We view our DR-CAPM results as suggesting that a unified view of risk markets is still possible.

To obtain an explanatory power similar to the DR-CAPM, the PCA analysis suggests using between four and eight principal components.[32] A naive approach that simply adds principal components leads to using the first eight principal components. The first two columns in Table 18 show that the resulting model must be discarded as many of the estimated prices of risk are not statistically significant.

A better model can be built using the information gleaned from the factor structure of each asset class. Since most of the explanatory power for the cross-section of each asset class comes from a slope factor, it is intuitive to suggest a model that only includes the slope factors of each asset class and a common level factor. The third and

[31] With the exception of the small-growth equity portfolio.

[32] We refer here to the principal components obtained by performing the PCA on the joint returns of currencies, equities, and commodities. Details of this PCA are reported in the appendix.

second to last columns in Tables 17 and 18 show that a model that uses the first and third principal components of the equity portfolios, the second principal component of the currency portfolios and the second principal component of the commodity portfolios or, alternatively, their mimicking portfolios (i.e. the market, HML_{ff}, carry and basis portfolios) performs similarly to the DR-CAPM. The estimated prices of risk are statistically significant for all slope component, or for their mimicking portfolios, but not for the level component or market return. This PCA-based model generates a R^2 of 59% and RMSPE of 0.19 when using the principal components and a R^2 of 70% and RMSPE of 0.16 when using the mimicking portfolios. The DR-CAPM performs similarly with a R^2 of 74% and RMSPE of 0.15 and is once again able to jointly summarize the information contained in all of these principal components in just two factors.

6.5. Other Factor Structures and Further Research

While the DR-CAPM is able to price returns in many important asset classes, it is not universally successful. In this section we present results for asset classes for which the DR-CAPM is not successful: momentum portfolios, corporate bonds and US Treasuries. Rather than estimating the full model, we plot the relationship of the downside risk beta with average returns in the bottom panels of Figure 16, while the top panels show the relationship of average returns with the standard CAPM beta.

The left panels of Figure 16 show results for equity portfolios sorted on momentum.[33] While the returns of these portfolios appear to be unrelated to beta, they are broadly positively associated with downside beta with the exception of the first momentum portfolio, which consists of small firms with very low recent returns. However, the association with downside beta is not sufficiently strong for the DR-CAPM to fully capture the returns of the momentum portfolios.

The middle panel shows results for US corporate bonds.[34] While the CAPM beta and the downside beta are both positively associated with these portfolio returns, the spread in average returns is too small compared to the spread in downside betas.

The right panels in Figure 16 show that the DR-CAPM performs worst on returns of US Treasuries of various maturities.[35] While bond returns are positively associated with their unconditional beta, they are actually negatively related to their downside beta. Cochrane and Piazzesi [19] have documented that the cross section of average bond returns is in fact driven by a single factor that is not strongly associated with market returns. Figure 16 shows that the bond factor is also not driven by downside market risk.

[33] We use six US equity portfolios sorted on size and momentum by Fama & French and available on Ken French's website. The sample period is from January 1974 to March 2010.

[34] We use the monthly returns on the five corporate bond portfolios sorted annually on their credit spread by Nozawa [43]. The sample period is from October 1975 to March 2010. Portfolio 1 is composed of the lowest credit spread bonds, portfolio 5 is composed of the highest credit spread bonds. The 5 portfolios are obtained by equally weighting the 10 portfolios in the benchmark analysis of Nozawa [43] into five baskets.

[35] We use the monthly bond returns in the Fama bond file of CRSP. The sample period is from January 1974 to March 2010. Portfolios 1-5 are formed with bonds with maturities less than or equal to one to five years, respectively. Portfolio 6 is formed with bonds with maturities less or equal than 10 years and portfolio 7 with bonds with maturities greater than 10 years.

Finally, we stress once more that our purpose was not to test a specific theoretical framework in the data, but to document a novel pattern, the exposure to downside risk, across many asset classes. Consequently, the model presented in Section 2 should not be regarded as a formal asset pricing model, but as an approximate reduced model form for asset returns that is convenient to highlight the novel risk exposure in the data. We are aware that the return data-generating-process, by the nature of its approximate form, will by construction misprice some assets whose payoffs are connected with the threshold property. Similarly, we have been intentionally silent on the deeper foundations of downside risk. It remains an open question for future research to derive models capable of matching the strong empirical patterns highlighted in this paper as well as providing a structural interpretation to the risk factors.

7. Conclusion

We find that currency returns are associated with aggregate market risk, thus supporting a risk-based view of exchange rates. However, we find that the unconditional CAPM cannot explain the cross section of currency returns because the spread in currency beta is not sufficiently large to match the cross sectional variation in expected returns. The downside risk CAPM (DR-CAPM) explains currency returns because the difference in beta between high and low yield currencies is higher conditional on bad market returns, when the market price of risk is also high, than it is unconditionally.

We also find that the DR-CAPM can jointly explain the cross section of currencies, equity, equity index options, commodities and sovereign bond returns. We view these results as not only confirming the empirical performance of the model but also as a first step in reconciling discount factors across asset classes. The performance of the model across asset classes contrasts with the failure of models designed for a specific asset class in pricing other asset classes.

Our results open new avenues for future research. Given its demonstrated empirical relevance, it is important to gain a deeper theoretical understanding of the sources and time variation of downside risk. It remains an open question whether downside risk comes from preferences or from micro-founded constraints.

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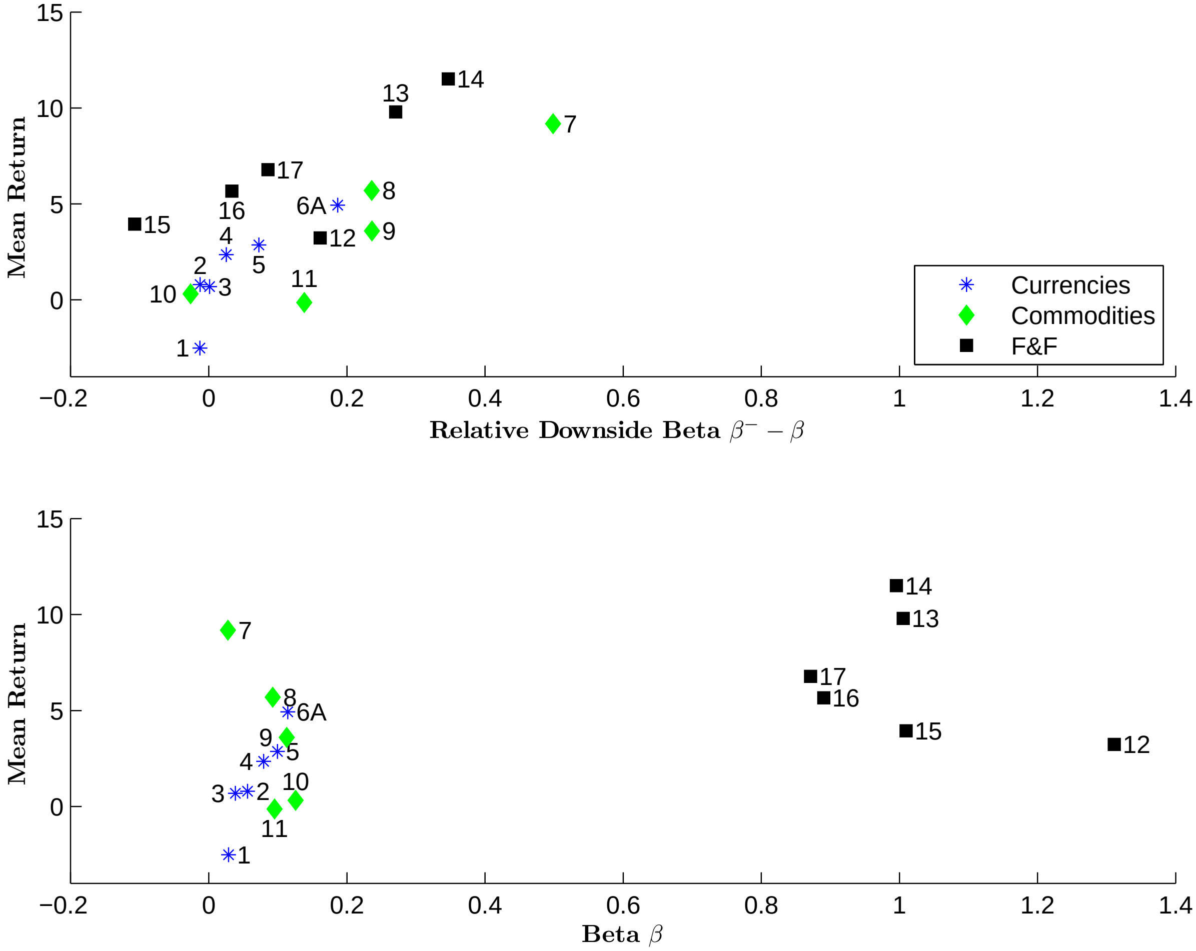
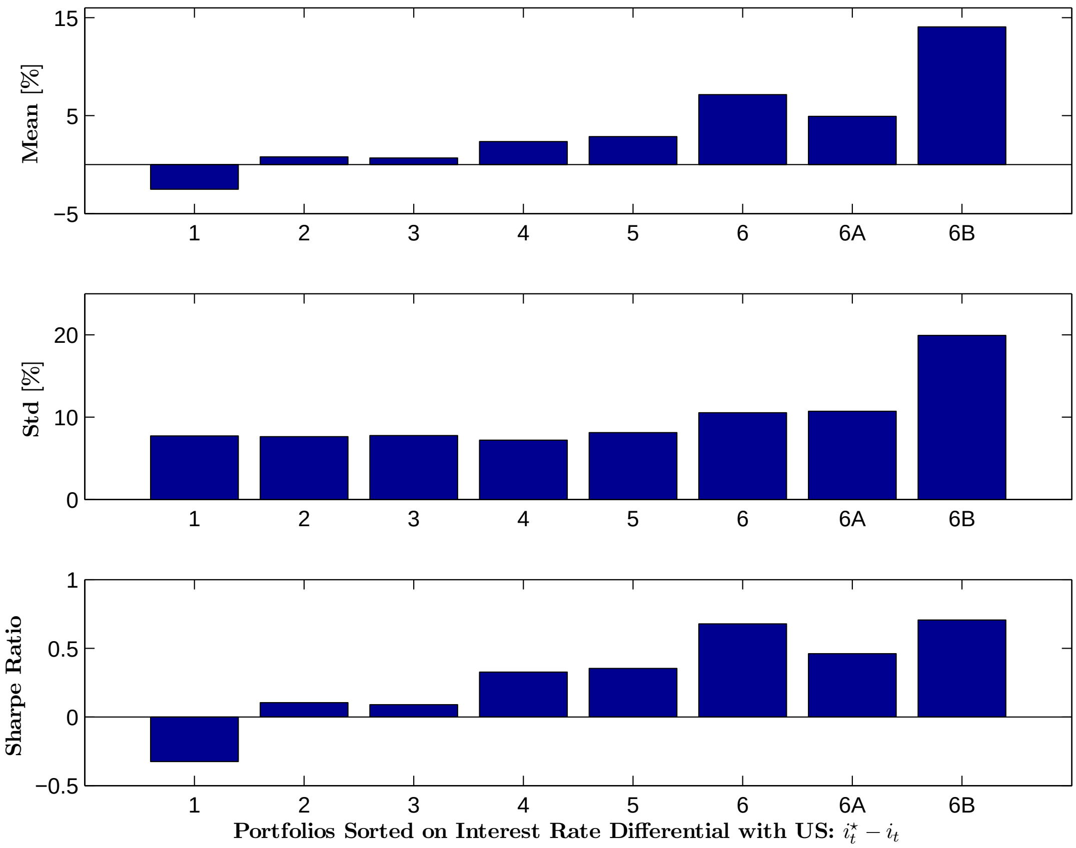
Figure 1: **Risk-Return Relations**



Risk-return relations for six currency portfolios monthly re-sampled based on the interest rate differential with the US, six Fama & French equity portfolios sorted on size and book to market, and five commodity futures portfolios monthly re-sampled based on basis. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The top panel plots the realized mean excess-return versus the relative downside betas ($\beta^{-} - \beta$). The bottom panel plots the realized mean excess-return versus the CAPM betas (β). The sample period is January 1974 to March 2010 for a total of 435 observations for the currency and equity portfolios, and January 1974 to December 2008 for a total of 420 observations for the commodity portfolios.

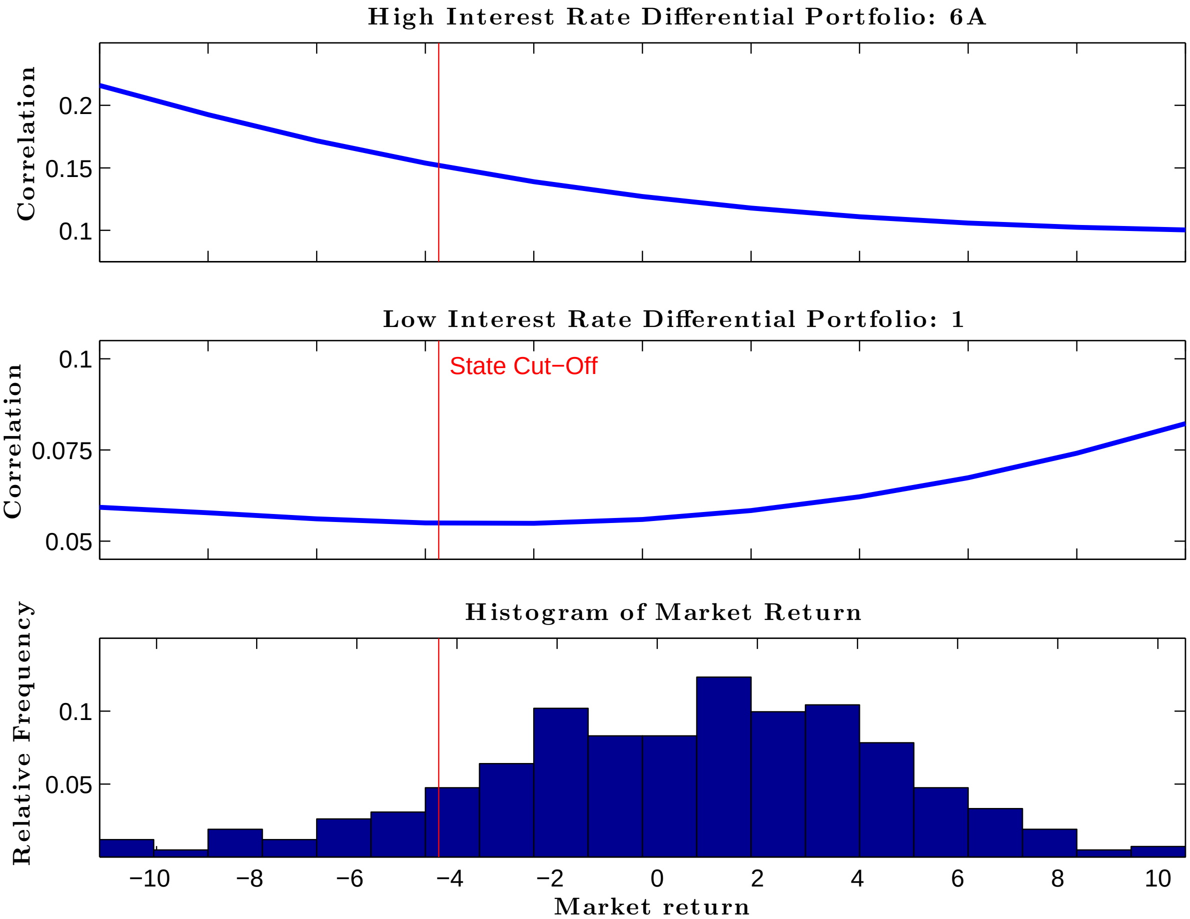
Figure 2: **Characteristics of the 6 Currency Portfolios**



Annualized mean excess-returns, standard deviations and Sharpe ratios for six currency portfolios, monthly re-sampled based on the interest rate differential with the US. High inflation countries in the sixth portfolio are subdivided into basket 6B. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations.

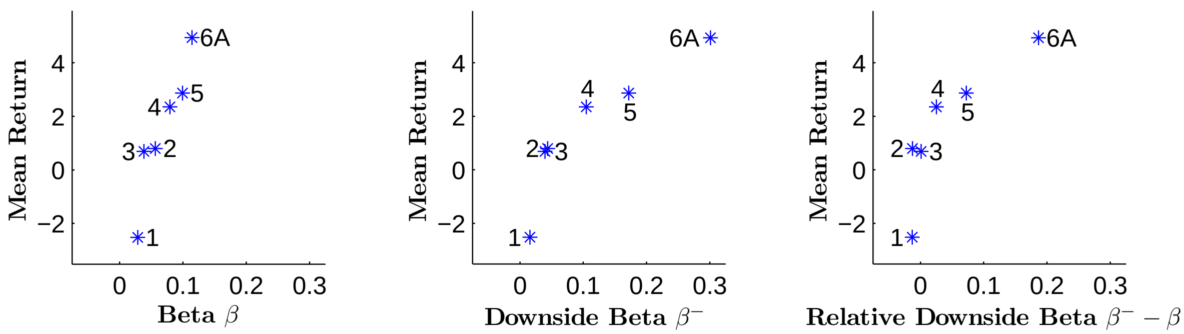
Student Version of MATLAB

Figure 3: **Kernel-Smoothed Conditional Correlation**



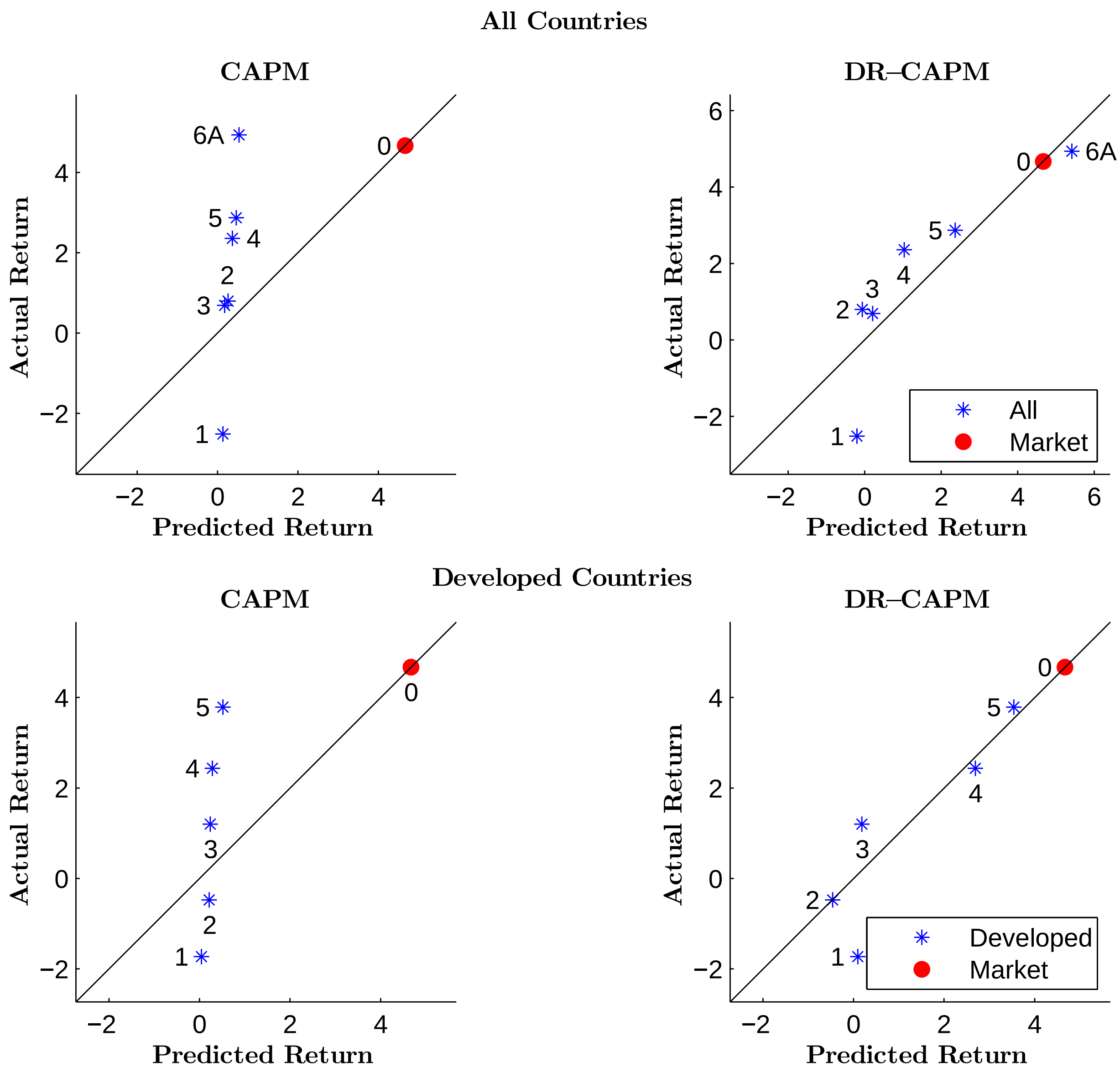
Kernel smoothed estimate of the conditional correlation between different currency portfolios and the CRSP value-weighted (market) excess-return conditional on the market excess-return using a normal kernel. Top panel: correlation of the market excess-return with the high interest rate currencies (portfolio 6A). High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. Middle panel: correlation of the market excess-return with the low interest rate currencies (portfolio 1). Bottom panel: empirical distribution of market excess-returns. The red line indicates the state cut-off in the empirical analysis of one standard deviation below the mean of the market excess-return. The graphs have been cut on the left and right at -/+10% monthly market excess-return. The sample period is January 1974 to March 2010 for a total of 435 observations.

Figure 4: **Risk-Return Relations: Currencies**



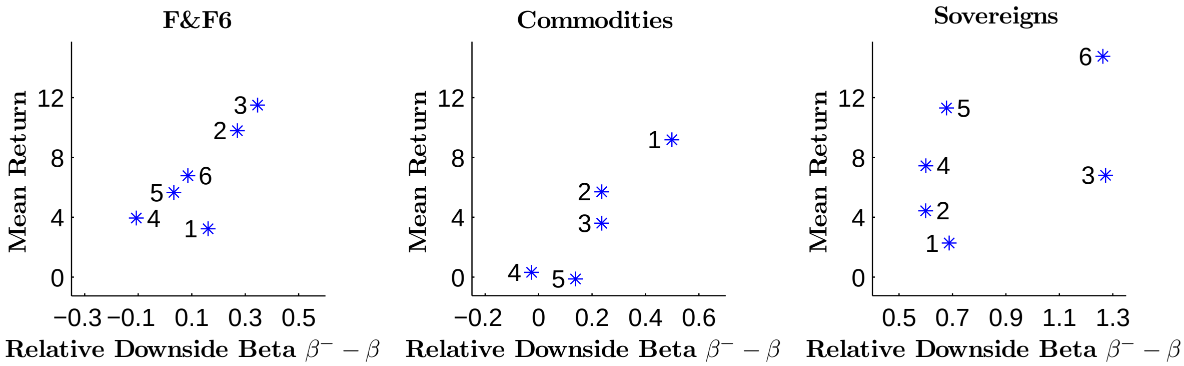
Risk-return relations for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. From left to right, the panels plot the realized mean excess-return versus the CAPM betas (β), the downside betas (β^-) and the relative downside betas ($\beta^- - \beta$). The sample period is January 1974 to March 2010 for a total of 435 observations.

Figure 5: **Model Performance: Currencies**



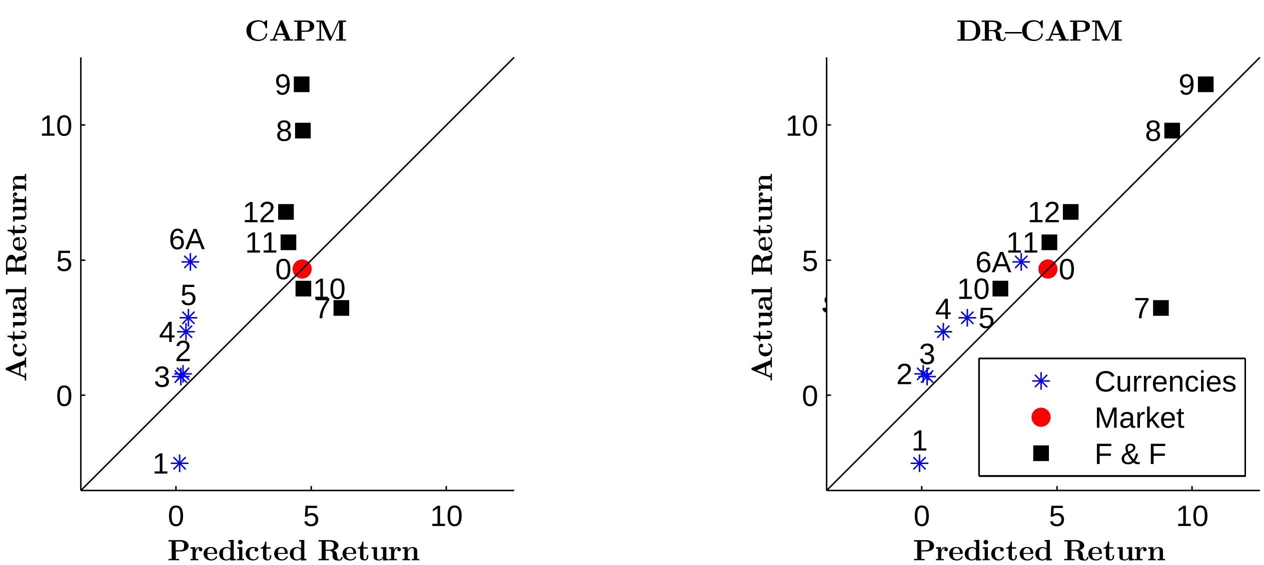
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels. In the top panel, test assets are six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. In the bottom panel, test assets are five currency portfolios of developed countries. The market excess-return is included as a test asset (0). The sample period is January 1974 to March 2010 for a total of 435 observations.

Figure 6: **Risk-Return Relations: Other Asset Classes**



Risk-return relations for the six Fama & French portfolios sorted on size and book-to-market (left panel), five commodity futures portfolios monthly re-sampled based on basis (middle panel), and six sovereign bond portfolios monthly re-sampled based on their probability of default and bond beta (right panel). The panels plot the realized mean excess-return versus the relative downside betas ($\beta^- - \beta$). The sample period is January 1974 to March 2010 for a total of 435 observations for the equity portfolios, January 1974 to December 2008 for a total of 420 observations for the commodity portfolios, and January 1995 to March 2010 for a total of 183 observations for the sovereign bond portfolios.

Figure 7: **Model Performance: Currencies and Equities**



Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panel and the downside risk CAPM (DR-CAPM) in the right panel. Test assets are six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US as well as the six Fama & French equity portfolios sorted on size and book-to-market (7-12). The market excess-return is included as a test asset (0). High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations.

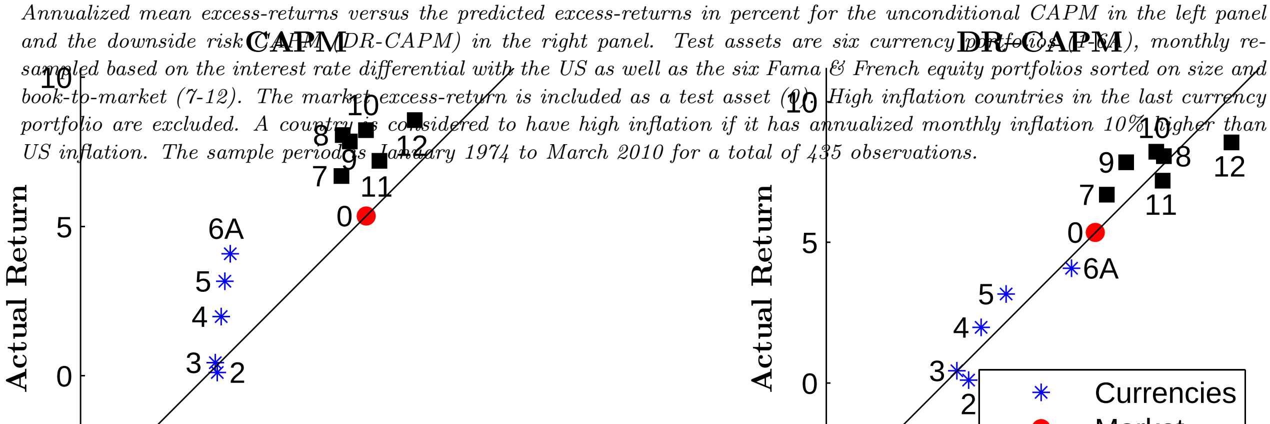
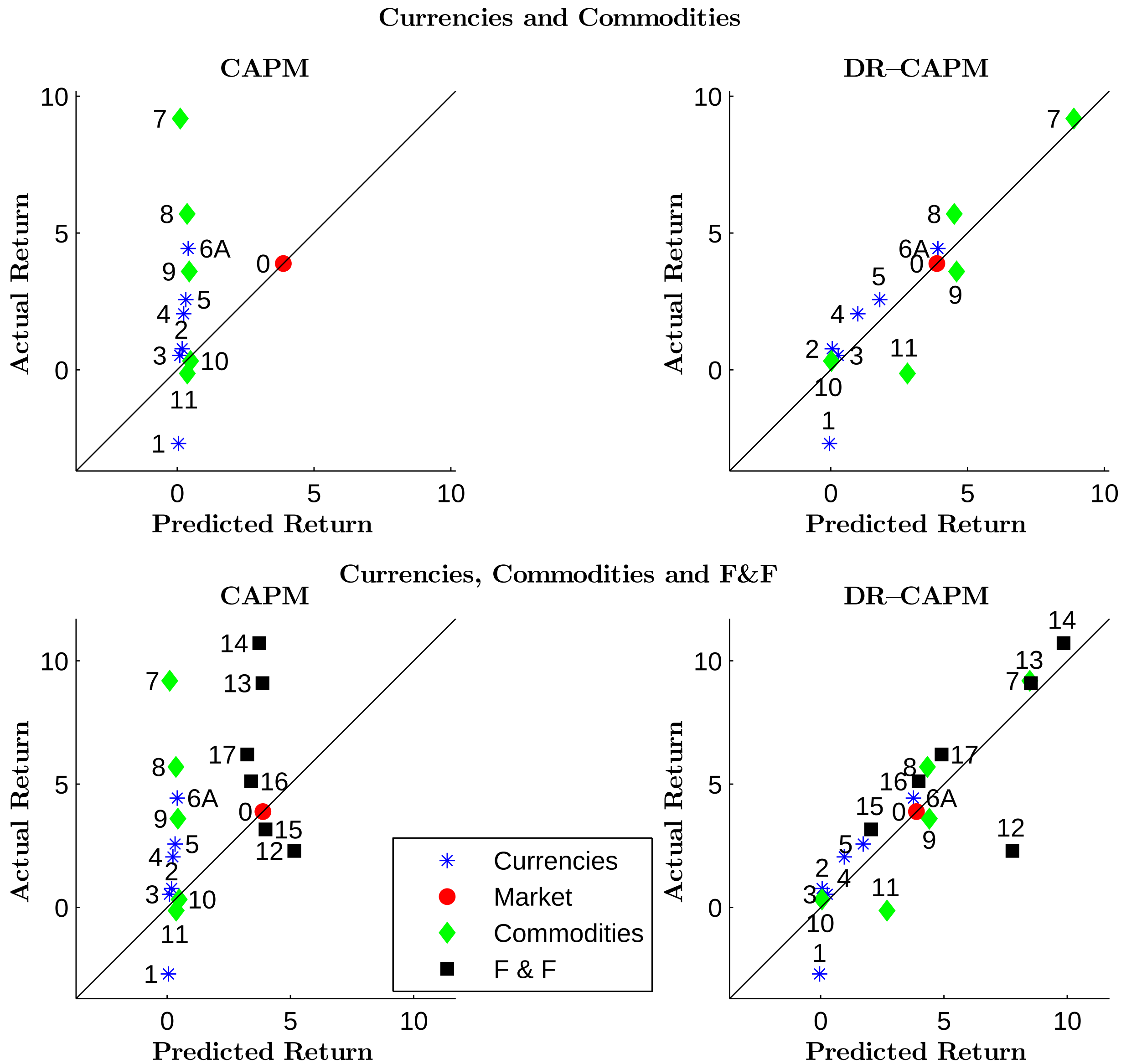
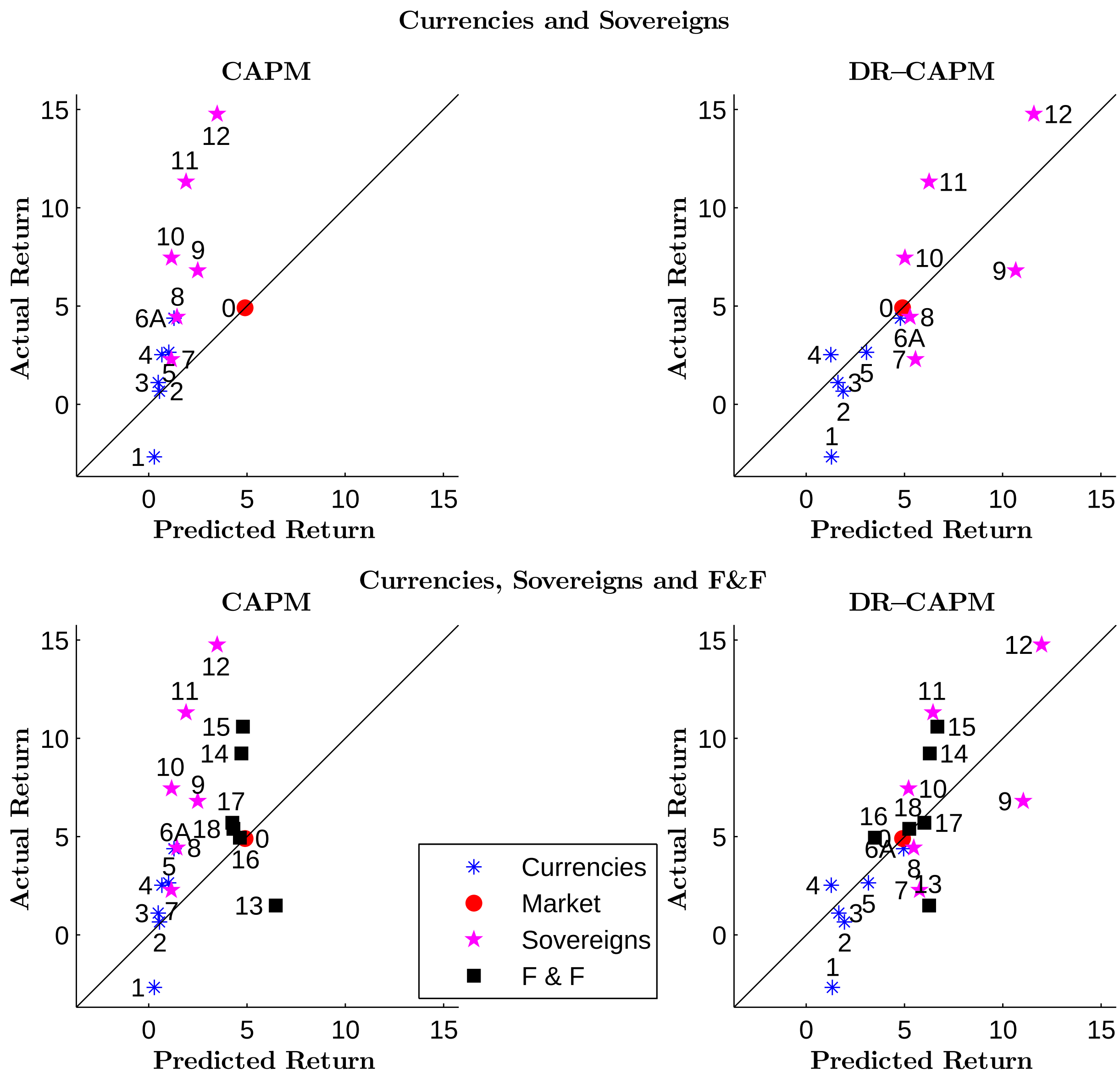


Figure 8: **Model Performance: Currencies, Equities, and Commodities**



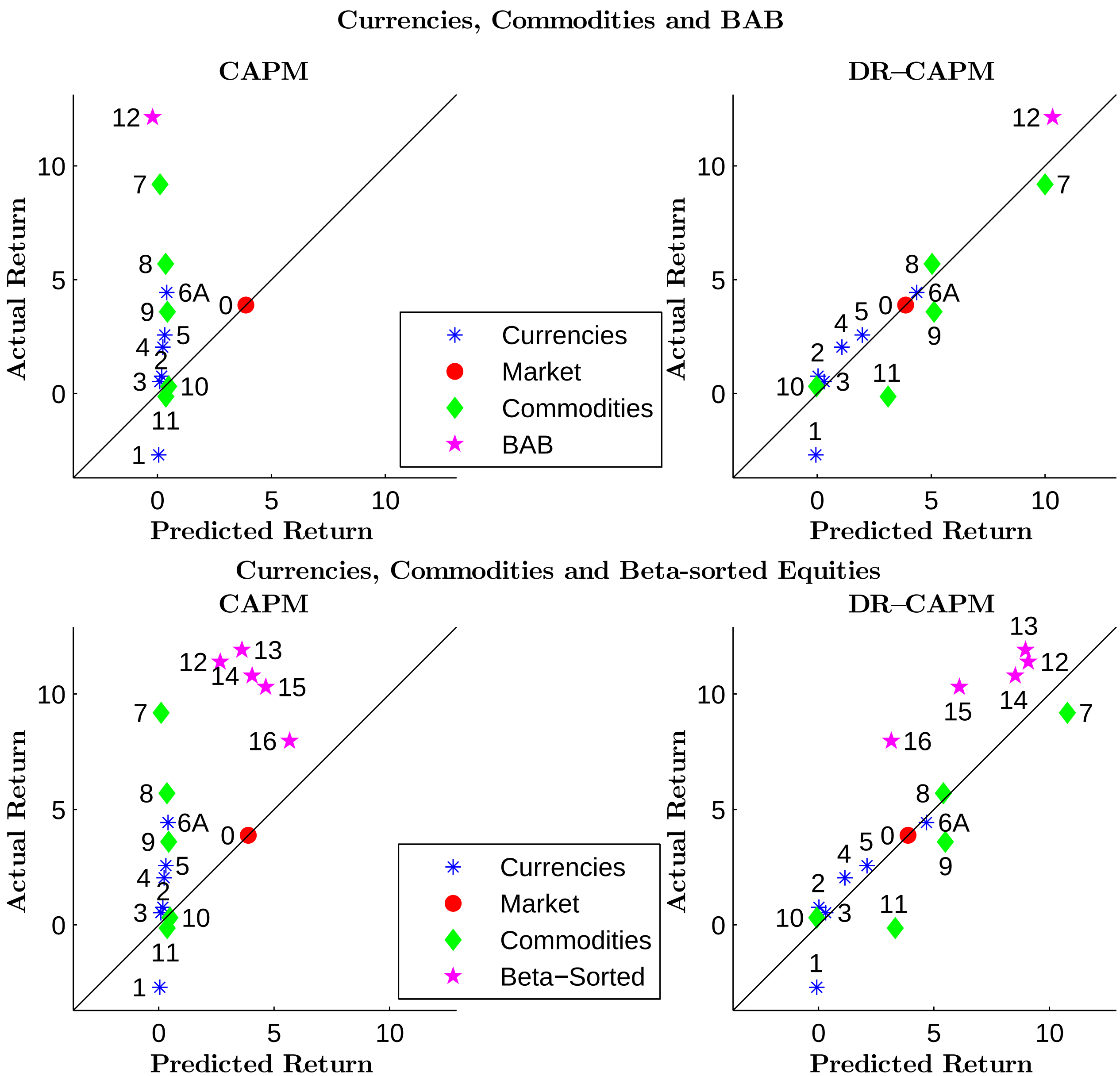
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis (labelled 7-11) as well as the six Fama & French portfolios sorted on size and book-to-market (12-17). The market excess-return is included as a test asset (0). High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation. The sample period is January 1974 to December 2008 for a total of 420 observations.

Figure 9: **Model Performance: Currencies, Equities, and Sovereign Bonds**



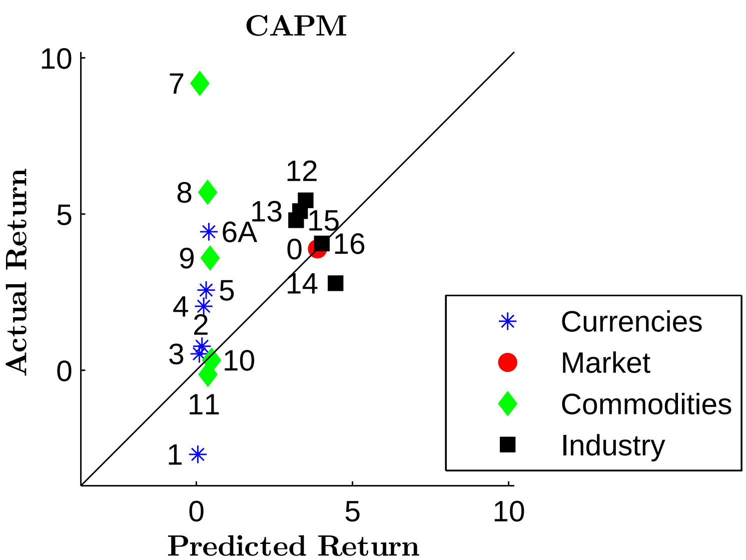
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US, six sovereign bond portfolios monthly re-sampled based on their probability of default and bond beta (7-12) as well as the six Fama & French portfolios sorted on size and book-to-market (13-18). The market excess-return is included as a test asset (0). High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation. The sample period is January 1995 to March 2010 for a total of 183 observations.

Figure 10: **Model Performance: Currencies, Commodities, and Beta-sorted Equities**



Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis (7-11) as well as the betting against beta factor (12) in the top panels and five portfolios sorted on CAPM beta (12-16) in the bottom panels. The market excess-return is included as a test asset (0). High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation. The sample period is January 1974 to December 2008 for a total of 420 observations.

Figure 11: **Model Performance: Currencies, Commodities, and Industry Portfolios**



Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panel and the downside risk CAPM (DR-CAPM) in the right panel. Test assets are six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis (7-11) as well as the five Fama & French industry portfolios (7-11). The market excess-return is included as a test asset (0). High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to December 2008 for a total of 420 observations.

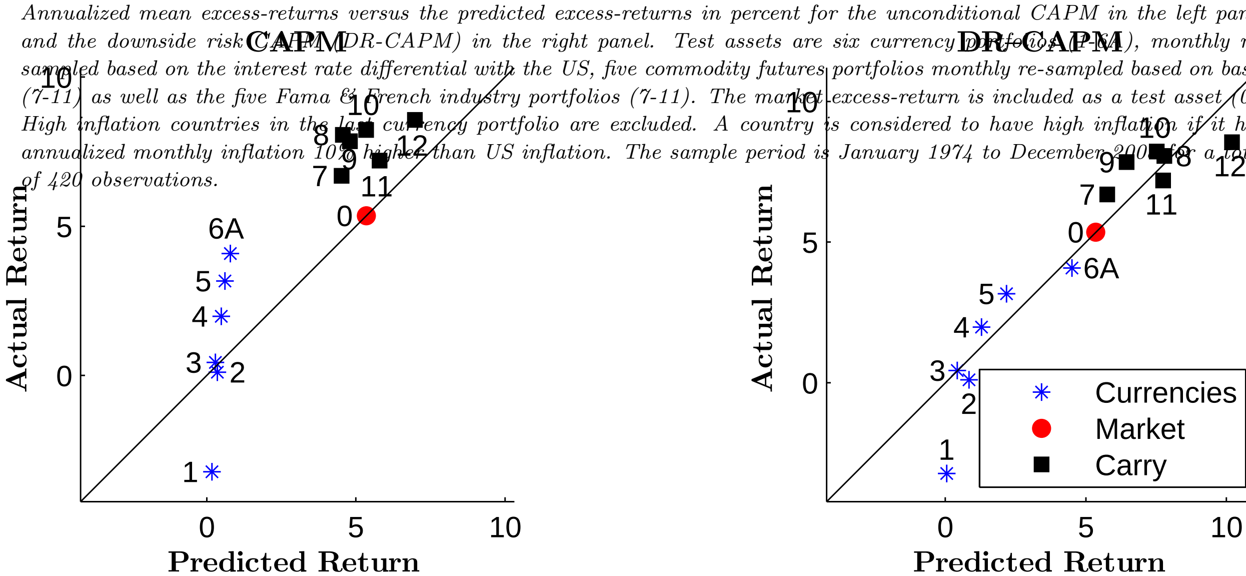
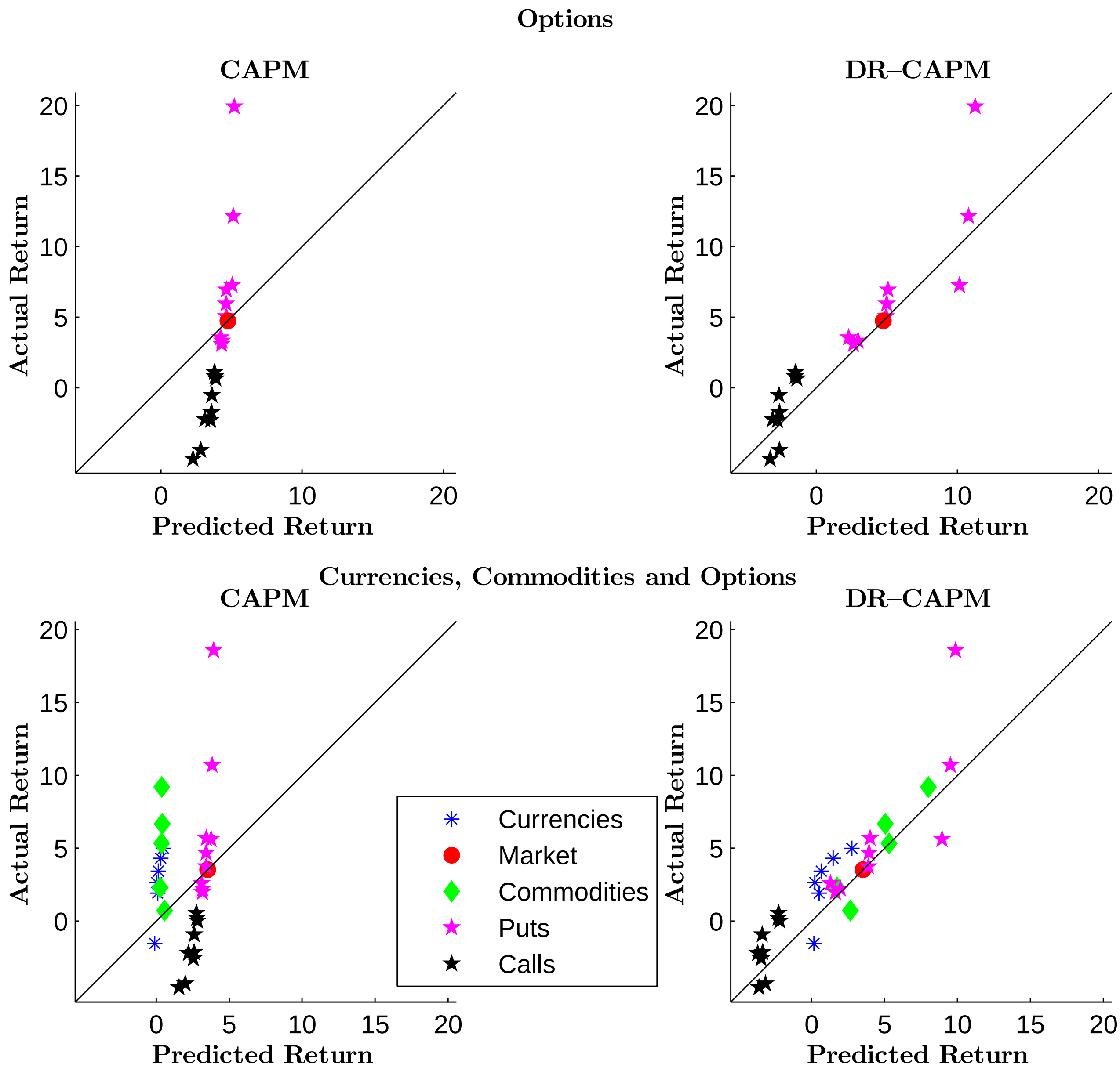
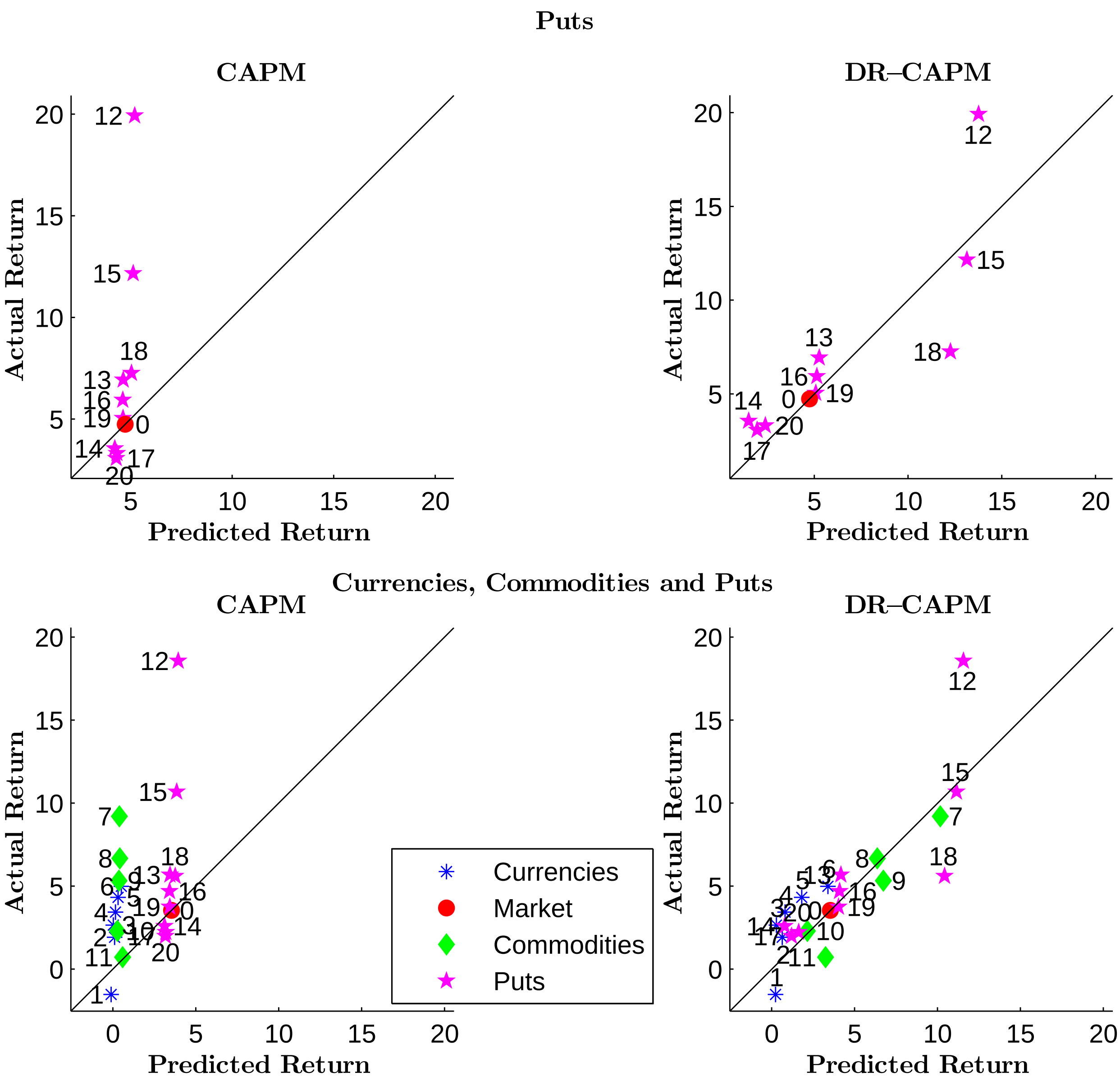


Figure 12: **Model Performance: Currencies, Commodities, and Equity Index Options**



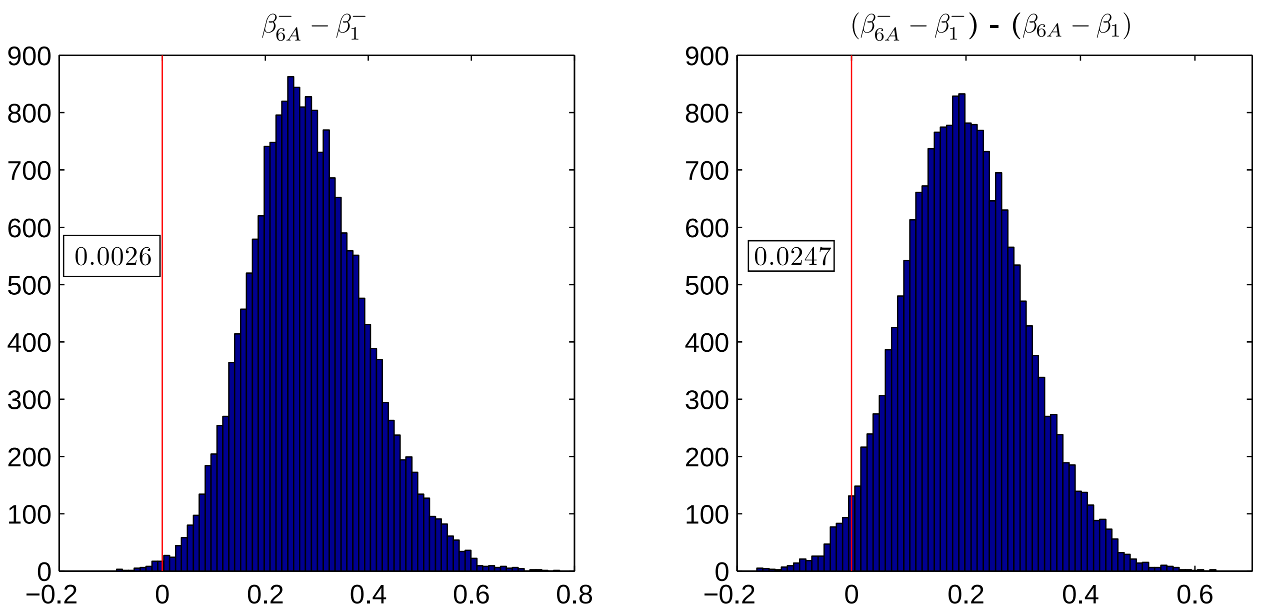
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels for six currency portfolios, monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis as well as 18 portfolios of call and put options on the S&P 500 with maturities between 30 and 90 days and moneyness between 90 and 110. The market excess-return is included as a test asset. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation. The sample period is April 1986 and to March 2010 for a total of 288 observations and to December 2008 for a total of 273 observations when the commodity portfolios are included.

Figure 13: **Model Performance: Currencies, Commodities, and Equity Index Puts**



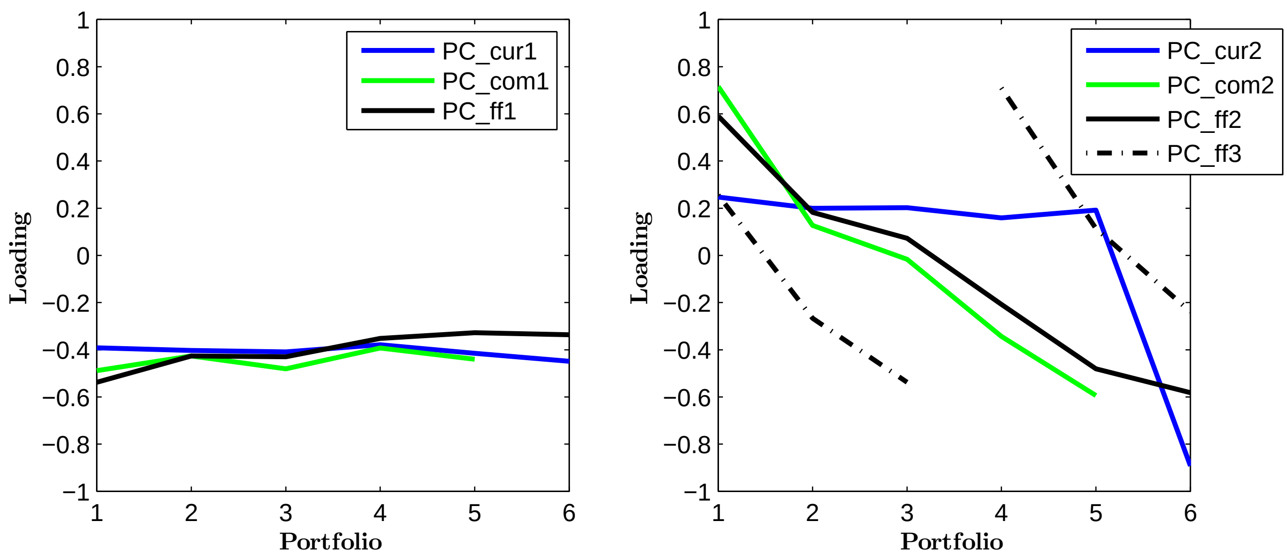
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis (7-11) as well as nine portfolios of put options on the S&P 500 with maturities between 30 and 90 days and moneyness between 90 and 110 (12-20). The market excess-return is included as a test asset (0). High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation. The sample period is April 1986 and to March 2010 for a total of 288 observations and to December 2008 for a total of 273 observations when the commodity portfolios are included.

Figure 14: **Bootstrapped Distribution: Currencies Relative Downstate Betas**



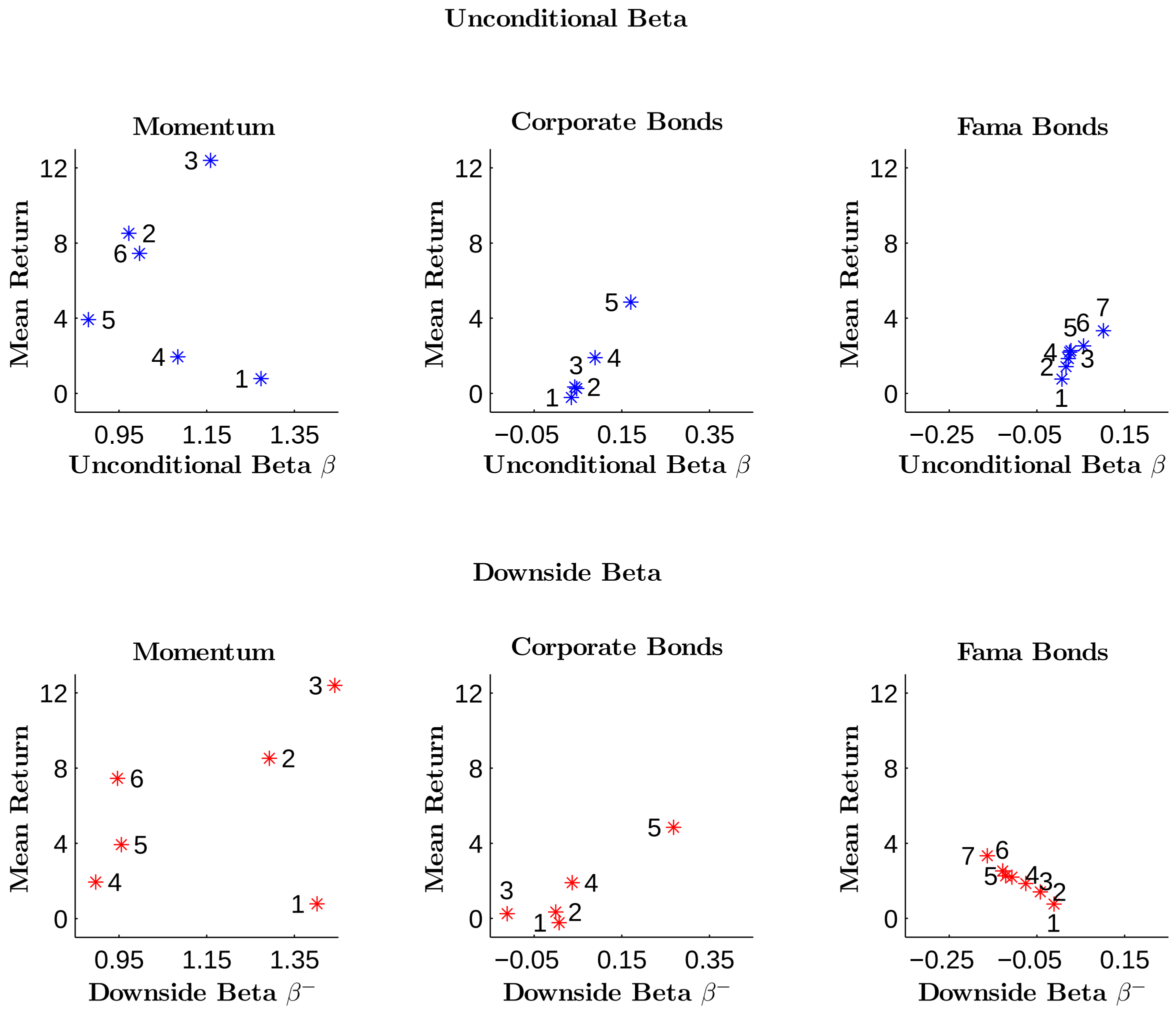
Bootstrapped distribution of the difference in downstate betas of the last and first currency portfolios, $\beta^-_{6A} - \beta^-_1$ in the left panel, and the difference in downstate minus unconditional betas of the last and first currency portfolios, $(\beta^-_{6A} - \beta^-_1)$ - $(\beta_{6A} - \beta_1)$, in the right panel. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation. We employ a smoothed bootstrap scheme consisting of re-sampling empirical residuals and adding zero centered normally distributed noise using 20,000 iterations.

Figure 15: **PCA Loadings: Currencies, Equities, and Commodities**



Loadings of the principal component analysis for six currency portfolios, monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis as well as the 6 Fama & French portfolios sorted on size and book-to-market. The PCA is performed separately on the portfolios of each asset class. The left panel plots the loadings of the first principal components of each asset class: PC_{cur1}, PC_{ff1}, *and* PC_{com1} *for currencies, equities, and commodities respectively. The right panel plots the loadings of the second principal component for currencies* (PC_{cur2}), *the second principal component for commodities* (PC_{com2}), *and the second and third principal components for equities* (PC_{ff2}, PC_{ff3}). *High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than the US. The sample period is January 1974 to March 2010 for a total of 435 observations for currencies and equities and to December 2008 for a total of 420 observations for the commodity portfolios.*

Figure 16: **Risk-Return Relations: T-Bills, Equity Momentum, and Corporate Bonds**



Risk-return relations for the 6 Fama & French portfolios sorted on size and momentum (left panels), five corporate bond portfolios annually re-sampled based on their credit spread by Nozawa [43] (middle panels), and seven zero coupon US Treasury bonds (right panels). The top panels plot the realized mean excess-return versus the CAPM beta (β), while the bottom panels plot the downside betas (β^{-}). The sample period is January 1974 to March 2010 for a total of 435 observations for the equity portfolios, October 1975 to March 2010 for a total of 414 observations for the commodity portfolios, and January 1974 to March 2010 for a total of 183 observations for the US Treasury bond portfolios.

Table 1: **Currency Portfolios**

Annualized sample means, standard deviations and Sharpe ratios for the interest rate differentials, spot exchange rate changes, excess returns and carry trade baskets for six currency portfolios, monthly re-sampled based on the interest rate differential with the US. High inflation countries in the sixth portfolio are subdivided into basket 6B. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations.

Int. Rate Diff.	Low	2	3	4	5	High	6A	6B
	Interest Rate Differential: $i^\star - i$							
Mean	-2.79	-0.56	1.11	2.97	5.59	22.01	12.58	36.02
Std	0.62	0.55	0.55	0.63	0.88	7.43	3.76	20.10
	Spot Change: Δs^j							
Mean	-0.27	-1.36	0.42	0.62	2.72	14.87	7.64	21.96
Std	7.63	7.56	7.70	7.19	8.11	10.27	11.30	15.87
	Excess Returns							
Mean	-2.52	0.79	0.69	2.35	2.87	7.14	4.94	14.06
Std	7.73	7.64	7.76	7.21	8.13	10.54	10.73	19.93
Sharpe Ratio	-0.33	0.10	0.09	0.33	0.35	0.68	0.46	0.71
	High minus Low: $rx^j - rx^1$							
Mean		3.31	3.21	4.87	5.38	9.66	7.45	16.14
Std		4.59	5.43	5.30	6.17	10.50	10.31	20.23
Sharpe Ratio		0.72	0.59	0.92	0.87	0.92	0.72	0.80

Table 2: **Equity, Commodity Futures, and Sovereign Bond Portfolios**

Annualized sample means, standard deviations and Sharpe ratios for portfolios of stock excess returns, commodity futures and sovereign bond returns. Panel A reports the statistics for the six Fama & French portfolios sorted on size and book-to-market. Panel B reports the statistics for 5 commodity futures portfolios monthly re-sampled based on basis. Panel C reports the statistics for 6 sovereign bond portfolios monthly re-sampled based on the probability of default and bond beta. The sample period is January 1974 to March 2010 for a total of 435 observations in the upper panel, January 1974 to December 2008 for a total of 420 observations in Panel B and January 1995 to March 2010 for a total of 183 observations in the lower panel.

	Panel A. Six Fama & French Portfolios					
Size		Small			Big	
Book-to-Market	Low	Medium	High	Low	Medium	High
Portfolio	1	2	3	4	5	6
Mean	3.23	9.80	11.51	3.94	5.66	6.78
Std	24.55	18.86	19.53	17.18	15.76	16.64
Sharpe Ratio	0.13	0.52	0.59	0.23	0.36	0.41

	Panel B. Commodity Futures Portfolios				
Basis	Low	2	3	4	High
Mean	9.18	5.70	3.59	0.32	-0.13
Std	18.50	15.65	16.38	15.58	17.34
Sharpe Ratio	0.50	0.36	0.22	0.02	-0.01

	Panel C. Sovereign Bond Portfolios					
Bond Beta		Low			High	
Credit Rating	Low	Medium	High	Low	Medium	High
Portfolio	1	2	3	4	5	6
Mean	2.28	4.43	6.80	7.45	11.32	14.77
Std	9.51	10.96	16.36	9.27	11.68	19.56
Sharpe Ratio	0.24	0.40	0.42	0.80	0.97	0.75

Table 3: **Beta-sorted Equities, Industry, and Equity Index Options Portfolios**

Annualized sample means, standard deviations and Sharpe ratios for portfolios of stock excess returns, industry and put and call option excess returns. Panel A reports the statistics for the 5 beta sorted stock portfolios and a betting against beta factor (BAB). Panel B reports the statistics for the 5 Fama & French industry portfolios. Panel C and D report the statistics for 9 put and call option portfolios on the S&P 500 with maturities between 30 and 90 days and moneyness between 90 and 110, respectively. The sample period is January 1974 to March 2010 for a total of 435 observations in Panels A and B and April 1986 to March 2010 for a total of 288 observations in Panels C and D.

Panel A. CAPM-Beta Sorted Equity Portfolios

Portfolio	Low	2	3	4	High	BAB
Mean	12.40	13.20	12.06	12.05	10.46	11.97
Std	14.47	18.08	20.17	23.23	30.16	12.18
Sharpe Ratio	0.86	0.73	0.60	0.52	0.35	0.98

Panel B. Fama & French Industry Portfolios

Industry	Consumer	Man.	HiTech	Health	Other
Portfolio	1	2	3	4	5
Mean	6.20	5.60	3.88	5.27	4.68
Std	16.43	15.66	20.95	17.88	18.95
Sharpe Ratio	0.38	0.36	0.19	0.29	0.25

Panel C. Equity Index Put Option Portfolios

Expiration	30	30	30	60	60	60	90	90	90
Moneyness	90	100	110	90	100	110	90	100	110
Portfolio	1	2	3	4	5	6	7	8	9
Mean	19.92	6.93	3.55	12.16	5.94	3.07	7.26	5.05	3.31
Std	22.39	17.79	15.82	21.23	17.61	16.09	20.57	17.60	16.22
Sharpe Ratio	0.89	0.39	0.22	0.57	0.34	0.19	0.35	0.29	0.20

Panel D. Equity Index Call Option Portfolios

Expiration	30	30	30	60	60	60	90	90	90
Moneyness	90	100	110	90	100	110	90	100	110
Portfolio	1	2	3	4	5	6	7	8	9
Mean	0.64	-2.31	-5.05	0.78	-1.76	-4.42	1.09	-0.54	-2.25
Std	14.76	14.37	13.60	14.61	14.42	14.00	14.45	14.34	14.41
Sharpe Ratio	0.04	-0.16	-0.37	0.05	-0.12	-0.32	0.08	-0.04	-0.16

Table 4: **Conditional Correlations: Carry Trade and Market Returns**

Correlations between the carry trade factor and CRSP value-weighted (market) excess-return. The correlation are computed unconditionally, in the upstate and downstate as well as for various inflation thresholds. Newey-West standard errors are reported in parentheses. Downstates are all months in which the market return is more than one standard deviation below its sample mean. The upstate includes all observations that are not included in the downstate. The sample period is January 1974 to March 2010 for a total of 435 observations.

	all	downstate	upstate
all countries	0.12	0.26	0.05
	(0.04)	(0.19)	(0.06)
excl high inflation (5%)	0.08	0.28	0.00
	(0.04)	(0.22)	(0.05)
excl high inflation (10%)	0.14	0.33	0.02
	(0.05)	(0.19)	(0.05)
excl high inflation (15%)	0.15	0.41	0.02
	(0.05)	(0.22)	(0.05)
developed countries	0.23	0.31	0.10
	(0.07)	(0.15)	(0.06)

Table 5: **Estimation of Linear Pricing Models: Currencies and Equities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). In the two left columns, test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The next two columns use five currency portfolios of developed countries as test assets and the rightmost two columns add the six Fama & French portfolios sorted on size and bool-to-market to the six currency portfolios. The market excess-return is included as a test asset. The sample period is January 1974 to March 2010 for a total of 435 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	All Currencies		Developed Currencies		Currencies and Equities	
	CAPM	DR-CAPM	CAPM	DR-CAPM	CAPM	DR-CAPM
λ	$0.39^\star$	$0.39^\star$	$0.39^\star$	$0.39^\star$	$0.39^\star$	$0.39^\star$
λ^-		2.18		2.34		1.41
		(0.77)		(1.05)		(0.40)
χ^2	42.28	24.60	22.36	9.81	114.54	63.39
p-val	0.00%	0.04%	0.10%	8.09%	0.00%	0.00%
RMSPE	0.19	0.09	0.15	0.07	0.26	0.16
R^2	8.77%	78.74%	34.74%	85.32%	24.31%	71.41%
T	435	435	435	435	435	435

Table 6: **Estimation of Linear Pricing Models: Currencies, Equities, Commodities and Sovereigns**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). In the left two columns, test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US and five commodity futures portfolios, monthly re-sampled based on basis. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The next two columns add the six Fama & French portfolios, sorted on size and book-to-market. The next two columns use the six currency portfolios and six sovereign bond portfolios, monthly re-sampled based on the probability of default and bond beta as test assets. The rightmost two columns add the six Fama & French portfolios, sorted on size and book-to-market. The market excess-return is included as a test asset. The sample period is January 1974 to December 2008 for a total of 420 observations in the left four columns and January 1995 to March 2010 for a total of 183 observations in the right four columns. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Currencies, and Commodities		Equities, Currencies, and Commodities		Currencies, and Sovereigns		Equities, Currencies and Sovereigns	
	CAPM	DR-CAPM	CAPM	DR-CAPM	CAPM	DR-CAPM	CAPM	DR-CAPM
λ	$0.32^\star$	$0.32^\star$	$0.32^\star$	$0.32^\star$	$0.41^\star$	$0.41^\star$	$0.41^\star$	$0.41^\star$
λ^-		1.47		1.40		0.53		0.56
		(0.53)		(0.38)		(0.21)		(0.21)
χ^2	52.66	28.24	128.27	64.48	40.26	39.68	88.31	86.54
p-val	0.00%	0.30%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%
RMSPE	0.30	0.11	0.31	0.15	0.41	0.22	0.38	0.22
R^2	-42.93%	80.69%	-17.38%	73.52%	-20.81%	65.80%	-22.66%	57.10%
T	420	420	420	420	183	183	183	183

Table 7: **Estimation of Linear Pricing Models: Currencies, Commodities, Beta-sorted and Industry-sorted Equities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). In the left two columns, test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios, monthly re-sampled based on basis as well as a betting against beta (BAB) factor. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The next two columns use five portfolios sorted on CAPM beta instead of the BAB factor. The rightmost two columns add the five Fama & French industry portfolios to the currency and commodity portfolios. The market excess-return is included as a test asset. The sample period is January 1974 to December 2008 for a total of 420 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	BAB, Currencies, and Commodities		Beta-sorted Equities, Currencies, and Commodities		Industry-sorted Equities, Currencies, and Commodities	
	CAPM	DR-CAPM	CAPM	DR-CAPM	CAPM	DR-CAPM
λ	0.32⋆	0.32⋆	0.32⋆	0.32⋆	0.32⋆	0.32⋆
λ^-		1.65		1.78		1.36
		(0.35)		(0.39)		(0.45)
χ^2	91.04	28.49	102.75	41.85	62.11	38.96
p-val	0.00%	0.47%	0.00%	0.04%	0.00%	0.01%
RMSPE	0.40	0.12	0.39	0.19	0.26	0.11
R^2	-58.66%	86.45%	-12.10%	74.55%	-32.80%	75.02%
T	420	420	420	420	420	420

Table 8: **Estimation of Linear Pricing Models: Currencies, Commodities, and Equity Index Options**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). In the left two columns, test assets are 18 portfolios of call and put options on the S&P 500 with maturities between 30 and 90 days and moneyness between 90 and 110. The right two columns add six currency portfolios, monthly re-sampled based on the interest rate differential with the US and five commodity futures portfolios monthly re-sampled based on basis. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is April 1986 and to March 2010 for a total of 288 observations and to December 2008 for a total of 273 observations when the commodity portfolios are included. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Options		Currencies, Commodities and Options	
	CAPM	DR-CAPM	CAPM	DR-CAPM
λ	$0.40^{\star}$	$0.40^{\star}$	$0.29^{\star}$	$0.29^{\star}$
λ^{-}		1.14		1.13
		(0.27)		(0.27)
χ^2	162.72	162.63	211.95	211.89
p-val	0.00%	0.00%	0.00%	0.00%
RMSPE	0.44	0.21	0.39	0.20
R^2	18.90%	81.43%	-1.89%	74.45%
T	288	288	273	273

Table 9: **Betas of First-Stage Times-Series Regressions: Currencies, Equities, and Commodities**

First-stage time series unconditional and downstate betas with OLS standard errors in parentheses for portfolios of currency, stock and commodity (excess-) returns. Panel A reports these statistics for six currency portfolios, monthly re-sampled based on the interest rate differential with the US. Panel B reports the statistics for the six Fama & French portfolios sorted on size and book-to-market. Panel C reports the statistics for 5 commodity futures portfolios monthly re-sampled based on the commodity basis. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations in Panel A and B and January 1974 to December 2008 for a total of 420 observations in Panel C.

	Panel A. Six Currency Portfolios						
Int. Rate Diff.	Low	2	3	4	5	High	6A
β	0.03	0.06	0.04	0.08	0.10	0.10	0.11
SE_{OLS}	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
β^-	0.02	0.04	0.04	0.10	0.17	0.18	0.30
SE_{OLS}	(0.10)	(0.10)	(0.09)	(0.08)	(0.10)	(0.10)	(0.13)

	Panel B. Six Fama & French Portfolios					
Size		Small			Big	
Book-to-Market	Low	Medium	High	Low	Medium	High
Portfolio	1	2	3	4	5	6
β	1.31	1.01	1.00	1.01	0.89	0.87
	(0.03)	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)
β^-	1.47	1.28	1.34	0.90	0.92	0.96
	(0.11)	(0.12)	(0.14)	(0.05)	(0.08)	(0.13)

	Panel C. Commodity Futures Portfolios				
Basis	Low	2	3	4	High
β	0.03	0.09	0.11	0.13	0.10
	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)
β^-	0.53	0.33	0.35	0.10	0.23
	(0.26)	(0.23)	(0.25)	(0.20)	(0.25)

Table 10: **Betas of First-Stage Times-Series Regressions: CAPM-beta Sorted, Industry, and Equity Index Option Portfolios**

First-stage time series unconditional and downstate betas with OLS standard errors in parentheses for portfolios of equity and equity index options excess returns. Panel A reports these statistics for five CAPM-beta sorted equity portfolios. Panel B reports the statistics for the five Fama & French industry portfolios. Panel C and D report the statistics for 9 put and call option portfolios on the S&P 500 with maturities between 30 and 90 days and moneyness between 90 and 110, respectively. The sample period is January 1974 to March 2010 for a total of 435 observations in Panels A and B, April 1986 to March 2010 for a total of 288 observations in Panels C and D.

Panel A. CAPM-beta Sorted Equity Portfolios

Portfolio	Low	2	3	4	High	BAB
β	0.69	0.93	1.04	1.20	1.46	-0.05
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.04)
β^-	0.99	1.18	1.25	1.26	1.34	0.48
	(0.10)	(0.11)	(0.10)	(0.11)	(0.13)	(0.15)

Panel B. Fama & French Industry Portfolios

Industry	Consumer	Man.	HiTech	Health	Other
Portfolio	1	2	3	4	5
β	0.90	0.85	1.15	0.82	1.04
	(0.02)	(0.02)	(0.03)	(0.04)	(0.02)
β^-	1.01	0.90	0.92	0.81	1.12
	(0.10)	(0.09)	(0.14)	(0.15)	(0.10)

Panel C. Equity Index Put Option Portfolios

Expiration	30	30	30	60	60	60	90	90	90
Moneyness	90	100	110	90	100	110	90	100	110
Portfolio	1	2	3	4	5	6	7	8	9
β	1.10	0.98	0.89	1.08	0.98	0.91	1.06	0.98	0.91
	(0.05)	(0.03)	(0.02)	(0.04)	(0.03)	(0.02)	(0.04)	(0.03)	(0.02)
β^-	1.54	1.01	0.75	1.50	1.00	0.79	1.44	1.00	0.81
	(0.24)	(0.13)	(0.08)	(0.18)	(0.12)	(0.08)	(0.16)	(0.12)	(0.09)

Panel D. Equity Index Call Option Portfolios

Expiration	30	30	30	60	60	60	90	90	90
Moneyness	90	100	110	90	100	110	90	100	110
Portfolio	1	2	3	4	5	6	7	8	9
β	0.82	0.74	0.48	0.81	0.76	0.59	0.80	0.76	0.66
	(0.02)	(0.03)	(0.04)	(0.02)	(0.03)	(0.04)	(0.02)	(0.032)	(0.03)
β^-	0.43	0.28	0.0.7	0.42	0.30	0.20	0.42	0.30	0.20
	(0.08)	(0.11)	(0.16)	(0.08)	(0.11)	(0.14)	(0.07)	(0.10)	(0.14)

Table 11: **Model Robustness**

Prices of risk, Fama&MacBeth standard errors in parentheses, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for the downside risk CAPM (DR-CAPM). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, and the six Fama & French portfolios, sorted on size and book-to-market where indicated. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. In the left two columns, market prices of risk are estimated based only on the six Fama & French portfolios and the market excess-return. The reported standard errors correspond to this estimation. The estimated prices of risk are then used to fit the six currency portfolios or the six currency portfolios and the Fama & French portfolios jointly. The next two columns vary the downstate cutoff. Downstate in the low (high) threshold specification are all months in which the market returns is more than 1.5 (0.5) standard deviations below its sample mean. The rightmost two columns vary the inflation cutoff. A country is considered to have high inflation if is has annualized monthly inflation 5% (15%) higher than US inflation. The market excess-return is included as a test asset. The sample period is January 1974 to March 2010 for a total of 435 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Currencies	Currencies and Equities	Currencies	Currencies	Currencies	Currencies
	Equity Prices of Risk		Low Downstate Threshold	High Downstate Threshold	5% Inflation Threshold	15% Inflation Threshold
λ	$0.39^\star$	$0.39^\star$	$0.39^\star$	$0.39^\star$	$0.39^\star$	$0.39^\star$
λ^-	1.27	1.27	1.95	2.72	2.55	2.13
	(0.45)	(0.45)	(0.49)	(0.84)	(0.94)	(0.60)
χ^2			23.38	16.27	23.94	25.21
p-val			0.07%	1.24%	0.05%	0.03%
RMSPE	0.12	0.16	0.15	0.09	0.09	0.09
R^2	66.62%	70.99%	47.16%	77.76%	80.20%	80.99%
T	435	435	435	435	435	435

Table 12: **PCA: Currencies, Equities, and Commodities**

Loadings (PC1-(5)6) and percentage of the total variance explained by each principal component of a principal components analysis on the covariance matrix of: Panel A, six currencies portfolios (Cur-PF1 – Cur-PF6A), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. Panel B, the six Fama & French portfolios (FF-PF1 – FF-PF6), sorted on size and book-to-market. Panel C, five commodity futures portfolios (Com-PF1 – Com-PF5), monthly re-sampled based on basis. The sample period is January 1974 to March 2010 in Panels A and B for a total of 435 observations, and to December 2008 in Panel C for a total of 420 observations.

Panel A. PCA Currency Portfolios

	PC1	PC2	PC3
Cur-PF1	-0.39	0.25	0.55
Cur-PF2	-0.40	0.20	0.37
Cur-PF3	-0.41	0.20	-0.05
Cur-PF4	-0.38	0.16	-0.15
Cur-PF5	-0.41	0.19	-0.73
Cur-PF6A	-0.45	-0.89	0.04
Explained	68.78%	17.76%	5.03%

Panel B. PCA Fama & French Portfolios

	PC1	PC2	PC3
FF-PF1	-0.54	0.59	0.26
FF-PF2	-0.43	0.18	-0.27
FF-PF3	-0.43	0.07	-0.54
FF-PF4	-0.35	-0.21	0.71
FF-PF5	-0.33	-0.48	0.11
FF-PF6	-0.34	-0.58	-0.24
Explained	86.37%	6.98%	4.73%

Panel C. PCA Commodity Portfolios

	PC1	PC2	PC3
Com-PF1	-0.49	0.72	0.41
Com-PF2	-0.43	0.13	-0.46
Com-PF3	-0.48	-0.02	-0.28
Com-PF4	-0.39	-0.34	-0.38
Com-PF5	-0.44	-0.59	0.63
Explained	59.99%	15.08%	10.45%

Table 13: **Correlations: Currencies, Equities, and Commodities**

Top panel: correlations between market excess return (Mrkt), dollar and carry currency portfolio returns (RX_cur and HML_cur) and the first two principal components of six currency portfolios sorted on the interest differential (PC_cur1 and PC_cur2), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation.. Middle panels: three Fama & French portfolio returns (Mrkt, SMB and HML_ff) and the first three principal components of the six Fama & French portfolios sorted on size and book-to-market (PC_ff1, PC_ff2 and PC_ff3). Bottom panels: market excess return (Mrkt), commodity and basis portfolio returns (RX_com and HML_com) and the first two principal components of five commodity futures portfolios sorted on basis (PC_com1 and PC_com2). The left panels report unconditional correlations while the right panels condition on the downstate. Downstates are all months in which the market return is more than one standard deviation below its sample mean. The sample period is January 1974 to March 2010 for a total of 435 observations in the top and middle panels and to December 2008 for a total of 420 observations in the bottom panels.

	All States						**Down States**					
	Mrkt	RX_cur	HML_cur	PC_cur1	PC_cur2		Mrkt	RX_cur	HML_cur	PC_cur1	PC_cur2	
Mrkt	1.00	0.17	0.14	-0.17	-0.09		1.00	0.17	0.33	-0.17	-0.28	
RX_cur	0.17	1.00	0.07	-1.00	0.02		0.17	1.00	0.13	-1.00	-0.06	
HML_cur	0.14	0.07	1.00	-0.09	-0.95		0.33	0.13	1.00	-0.15	-0.97	
PC_cur1	-0.17	-1.00	-0.09	1.00	0.00		-0.17	-1.00	-0.15	1.00	0.08	
PC_cur2	-0.09	0.02	-0.95	0.00	1.00		-0.28	-0.06	-0.97	0.08	1.00	
	Mrkt	SMB	HML_ff	PC_ff1	PC_ff2	PC_ff3	Mrkt	SMB	HML_ff	PC_ff1	PC_ff2	PC_ff3
Mrkt	1.00	0.25	-0.33	-0.95	-0.15	0.23	1.00	0.45	0.00	-0.91	0.01	-0.16
SMB	0.25	1.00	-0.23	-0.48	0.80	-0.36	0.45	1.00	0.02	-0.64	0.66	-0.44
HML_ff	-0.33	-0.23	1.00	0.24	-0.51	-0.82	0.00	0.02	1.00	-0.27	-0.66	-0.90
PC_ff1	-0.95	-0.48	0.24	1.00	0.00	0.00	-0.91	-0.64	-0.27	1.00	-0.02	0.49
PC_ff2	-0.15	0.80	-0.51	0.00	1.00	0.00	0.01	0.66	-0.66	-0.02	1.00	0.30
PC_ff3	0.23	-0.36	-0.82	0.00	0.00	1.00	-0.16	-0.44	-0.90	0.49	0.30	1.00
	Mrkt	RX_com	HML_com	PC_com1	PC_com2		Mrkt	RX_com	HML_com	PC_com1	PC_com2	
Mrkt	1.00	0.11	-0.05	-0.11	-0.08		1.00	0.20	0.19	-0.20	0.21	
RX_com	0.11	1.00	0.05	-1.00	-0.02		0.20	1.00	0.07	-1.00	0.04	
HML_com	-0.05	0.05	1.00	-0.07	0.95		0.19	0.07	1.00	-0.09	0.95	
PC_com1	-0.11	-1.00	-0.07	1.00	0.00		-0.20	-1.00	-0.09	1.00	-0.05	
PC_com2	-0.08	-0.02	0.95	0.00	1.00		0.21	0.04	0.95	-0.05	1.00	

Table 14: **Estimation of Linear Pricing Models: Currencies**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The three leftmost columns present models based on the first three principal components of the test assets (PC1, PC2 and PC3). The fourth column presents the dollar and carry portfolio returns of Lustig and Verdelhan [36] (RX_{cur} and HML_{cur}). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC1	PC2	LRV	DR-CAPM
PC1	-0.33	-0.33		
	(0.23)	(0.23)		
PC2		-0.32		
		(0.12)		
PC3				
RX_{cur}			0.13	
			(0.09)	
HML_{cur}			0.47	
			(0.15)	
λ_{market}				$0.39^{\star}$
λ_{-}				2.18
				(0.77)
χ^2	43.24	36.05	25.14	24.60
p-val	0.00%	0.00%	0.00%	0.02%
RMSPE	0.19	0.14	0.12	0.10
R^2	4.47%	50.07%	63.71%	73.04%
T	435	435	435	435

Table 15: **Estimation of Linear Pricing Models: Equities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The three leftmost columns present models based on the first three principal components of the test assets (PC1, PC2 and PC3). The fourth column presents the three Fama & French portfolio returns (Mrkt, SMB and HML_ff). Test assets are the six Fama & French portfolios sorted on size and book-to-market. The last column excludes the small growth portfolio. The sample period is January 1974 to March 2010 for a total of 435 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC2	PC3	F&F	DR-CAPM	DR-CAPM *excl port 1*
PC1	-1.37	-1.37			
	(0.60)	(0.60)			
PC2	-0.25	-0.25			
	(0.17)	(0.17)			
PC3		-0.51			
		(0.14)			
Mrkt			0.36		
			(0.23)		
SMB			0.19		
			(0.15)		
HML_ff			0.49		
			(0.15)		
λ_{market}				$0.39^{\star}$	$0.39^{\star}$
λ_{-}				1.27	1.61
				(0.45)	(0.43)
χ^2	55.58	42.15	41.77	33.83	9.43
p-val	0.00%	0.00%	0.00%	0.00%	5.12%
RMSPE	0.25	0.14	0.14	0.20	0.07
R^2	-3.57%	67.25%	68.27%	32.93%	90.48%
T	435	435	435	435	435

Table 16: **Estimation of Linear Pricing Models: Commodities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The three leftmost columns present models based on the first three principal components of the test assets (PC1, PC2 and PC3). The fourth column presents the commodity and basis portfolio returns of Yang [46] (RX_{com} and HML_{com}). Test assets are five commodity futures portfolios, monthly re-sampled based on basis. The sample period is January 1974 to December 2008 for a total of 420 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC1	PC2	Yang	DR-CAPM
PC1	-0.73	-0.73		
	(0.41)	(0.41)		
PC2		0.60		
		(0.20)		
PC3				
RX_{com}			0.31	
			(0.18)	
HML_{com}			0.83	
			(0.28)	
λ_{market}				$0.32^{\star}$
λ_{-}				1.42
				(0.57)
χ^2	9.33	0.68	2.37	2.42
p-val	5.34%	87.84%	49.90%	65.98%
RMSPE	0.27	0.05	0.10	0.12
R^2	10.41%	96.83%	87.14%	81.61%
T	420	420	420	420

Table 17: **Estimation of Linear Pricing Models: Currencies, Equities, and Commodities (Mimicking Portfolios)** *Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The leftmost column presents the model based on the dollar and carry portfolio returns of Lustig and Verdelhan [36] (RX_{cur} and HML_{cur}). The second column presents the model based on the commodity and basis portfolio returns of Yang [46] (RX_{com} and HML_{com}). The third column presents a model based on the three Fama-French factors (Mrkt, SMB and HML_ff). The next two columns present models based on combinations of the portfolio returns in the previous three columns. Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, the six Fama & French portfolios sorted on size and book-to-market and five commodity futures portfolios, monthly re-sampled based on basis. The sample period is January 1974 to December 2008 for a total of 420 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.*

	Cur_{mim}	Com_{mim}	FF_{mim}	Cur_{mim} Com_{mim} FF_{mim}	Cur_{mim} Com_{mim} FF_{mim}	DR-CAPM
RX_{cur}	0.19			0.10		
	(0.11)			(0.10)		
HML_{cur}	0.99			0.42	0.50	
	(0.37)			(0.15)	(0.16)	
RX_{com}		0.43		0.31		
		(0.19)		(0.18)		
HML_{com}		0.54		0.83	0.91	
		(0.31)		(0.28)	(0.29)	
Mrkt			0.28	0.31	0.40	
			(0.23)	(0.23)	(0.24)	
SMB			0.23	0.18		
			(0.16)	(0.16)		
HML			0.57	0.49	0.49	
			(0.18)	(0.15)	(0.17)	
λ_{market}						$0.32^{\star}$
λ_{-}						1.40
						(0.38)
χ^2	113.18	120.09	107.48	84.30	87.49	64.48
p-val	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RMSPE	0.32	0.34	0.24	0.12	0.16	0.15
R^2	-14.96%	-35.22%	35.29%	82.37%	69.50%	73.52%
T	420	420	420	420	420	420

Table 18: **Estimation of Linear Pricing Models: Currencies, Equities, and Commodities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE), the number of observations T and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The two leftmost columns present models based on the first eight principal components of the test assets (PC1 – PC8). The third column presents a model based on the first two principal components of the currency portfolios (PC_cur1 and PC_cur2). The fourth column presents a model based on the first two principal components of the commodity portfolios (PC_com1 and PC_com2). The fifth column presents a model based on the first three principal components of the stock portfolios (PC_ff1 – PC_ff3). The sixth and seventh columns present models based on combinations of the principal components in the previous three columns. Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, the six Fama & French portfolios sorted on size and book-to-market and five commodity futures portfolios, monthly re-sampled based on basis. The sample period is January 1974 to December 2008 for a total of 420 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC7	PC8	PC_cur	PC_com	PC_ff	PC_cur PC_com PC_ff	PC_cur PC_com PC_ff	DR-CAPM
PC1 / PC_cur1	-1.32	-1.32	-0.55			-0.27		
	(0.60)	(0.60)	(0.28)			(0.24)		
PC2 / PC_cur2	0.55	0.55	-0.73			-0.28	-0.29	
	(0.40)	(0.40)	(0.27)			(0.12)	(0.12)	
PC3 / PC_com1	0.08	0.08		-0.97		-0.72		
	(0.23)	(0.23)		(0.42)		(0.41)		
PC4 / PC_com2	-0.57	-0.57		0.35		0.60	0.59	
	(0.20)	(0.20)		(0.23)		(0.20)	(0.20)	
PC5 / PC_ff1	-0.24	-0.24			-1.26	-1.22	-1.26	
	(0.18)	(0.18)			(0.60)	(0.60)	(0.60)	
PC6 / PC_ff2	0.22	0.22			-0.21	-0.25		
	(0.16)	(0.16)			(0.17)	(0.17)		
PC7 / PC_ff3	0.10	0.10			-0.63	-0.52	-0.58	
	(0.15)	(0.15)			(0.18)	(0.14)	(0.18)	
PC8		-0.60						
		(0.14)						
λ_{market}								$0.32^{\star}$
λ_{-}								1.40
								(0.38)
χ^2	111.56	93.14	123.01	118.39	107.72	91.80	97.69	64.48
p-val	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RMSPE	0.19	0.12	0.33	0.34	0.24	0.12	0.19	0.15
R^2	59.08%	83.03%	-28.62%	-35.32%	36.07%	83.62%	59.48%	73.52%
T	420	420	420	420	420	420	420	420